TESTS OF SPIRAL-HOOPED CONCRETE COLUMNS

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THESIS

FOR THE

DEGREE OF BACHELOR OF SCIENCE

IN

CIVIL ENGINEERING

IN THE

COLLEGE OF ENGINEERING

UNIVERSITY OF ILLINOIS

PRESENTED, JUNE, 1909

Q.624
Ta09j

UNIVERSITY OF ILLINOIS

June 1, 1909

THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

CHARLES AUSTIN JAMES and GUY RAY SHAW

ENTITLED TESTS OF SPIRAL-HOOPED CONCRETE COLUMNS

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Bachelor of Science in Civil Engineering

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I. INTRODUCTION.

1. Historical Sketch.- The first use made of reinforced concrete was in the construction of a small boat which was exhibited at the Paris Exposition by Lambot in 1855. In 1861 the construction of beams, arches, pipes, etc., was advocated by Coignet, by whom patents were taken out on his system of reinforcement, this system and slight modifications of it being used quite extensively at the present time. This form of construction, however, owing to the lack of experimental knowledge of the subject and to the abundance and consequent low price of lumber, was very little used up to within the last decade.

But in the last decade reinforced concrete construction has had a remarkable development. The increase in the price of good lumber has made some substitute for it as a building material necessary. The ease with which certain parts of structures may be fabricated in place, the fireproof and rust-proof qualities and the comparatively low cost of cement concrete, has given a very apt substitute in the form of reinforced concrete. It has, within the last few years, come to be regarded by engineers and architects generally as a safe form of construction with a wide field of application. Common practice has established itself in some directions and some rational principles, established by experimental knowledge are available.

2. Available Data.- The greaternumber of tests which have been made to determine the value of concrete when used as columns have

been made on small specimens such as cubes, cylinders, and small columns with very few on columns of a size used in building construction.

Of these latter tests those familiar to and used to some extent by the writers are three series made under the supervision of Prof. A. N. Talbot by the University of Illinois Engineering Experiment Station. The first of these is treated in Bulletin No. 10 of the University of Illinois Engineering Experiment Station and also in the thesis of Mr. R. C. Llewellyn of the Class of '06. The second of these series is reported in Bulletin No. 20 of the University of Illinois Engineering Experiment Station and in the thesis of Messrs. Grear, Hoff and Mowder of the Class of '07. The last of these series has been reported in the following theses: (1) Tests of Spiral-Hooped Concrete Columns, by Messrs. Gonnerman, Slaymaker and Weber, (2) Tests of Plain Concrete Columns by Messrs. Burch and Heany, and (3) Tests of Band-hooped Columns by Messrs Burroughs, Grubel and Hudson. The results of this series will be presented later in a bulletin from the University of Illinois Engineering Experiment Station.

3. Scope of Thesis.- In the present series several methods of reinforcement were used, namely; (1) spiral hooping, (2) longitudinal rods, (3) a combination of spiral hooping and longitudinal rods, and (4) structural shapes. In addition to these columns several plain concrete columns were tested. This thesis treats with spiral reinforcement only.

For this thesis twenty-two columns with spiral reinforcement were tested. They were generally cylindrical and approximately 12 inches in diameter, but varied in length.

The immediate purposes of the tests were two-fold, first to determine the effect of length on the strength of the columns, and second to determine the effect of the pitch and size of spiral upon the strength of the column.

As shown by Table No. 5, page 16, there were available for the first of these purposes 13 columns varying in length from 5 ft. 1½ in. to 19 ft. 9 in., all being reinforced with a ¼-in. spiral and a 1-in. pitch. As shown by the same table there were, for the second purpose, 13 columns available, all of approximately 10 feet in length and containing the same percent of reinforcement but varying in the pitch of the spiral.

II. MATERIALS, TEST PIECES AND METHOD OF TESTING.

1. Materials.- The materials used in making the concrete for the columns were sand, crushed limestone, and Portland cement, similar to those employed in the best concrete construction in this section of the country. All of the cement was furnished by the manufacturers, the Universal Portland Cement Co. of Chicago, but the sand and stone were bought in the open market.

(a) Stone.- The crushed limestone was shipped from Kankakee, Illinois, in car load lots, which varied more or less in regard to fineness. An average of three tests, made by immersing a box of stone in water showed the stone to contain 48.5% voids.

Table 1 shows the average of 22 mechanical analyses of the stone used.

Table 1.

Mechanical Analysis of Stone.

Sieve in.	Per cent Passing
3/4	87.9
1/2	51.01
3/8	29.36
No. 3	13.65
No. 5	1.76
No. 10	0.94

(b) Sand.- The sand was shipped from Attica, Indiana. It was clear, sharp and well graded. The percent voids as obtained from the average of three tests was 46.53. Table 2 gives the results of a mechanical analysis, each value given being the average of 18 tests.

Table 2.

Mechanical Analysis of Sand.

Sieve No.	Per cent Passing
3	99.66
5	95.90
10	76.90
12	69.83
16	62.85
18	51.56
30	26.99
40	16.93
50	5.82
74	3.12
150	0.80

(c) Cement.- Universal Portland cement was used exclusively in the making of the columns, being furnished by the manufacturers. The results of fineness tests are given in Table 3. The tensile strength of standard briquettes, both of neat cement and of a 1–3 mixture, with Ottawa sand, is given in Table 4. The percent of water used was 22% of the total volume of the cement, or sand and cement. Each value given is the average of five briquettes.

Table 3.

Fineness Tests of Cement

Sieve No.	Per cent Passing
75	98.8
100	96.3
200	81.3

Table 4.

Tensile Strength of Cement

Ref. No.	7 day test		28 day test	
	Neat	1–3	Neat	1–3
1	595	179	772	280
2	617	160	853	278
Av.	606	169.5	812.5	279

(d) Concrete.- The concrete was made by men who have had considerable experience in the mixing of concrete for test purposes and also in concrete construction. The condition and methods employed in the fabrication of the columns were similar to those met with in ordinary concrete construction.

One mixture was used throughout, namely, 1 part cement, 2 parts sand, 4 parts broken stone; the materials being measured by loose volume and checked by the weight.

The mixing was conducted in the following manner: 18 buckets of sand was spread out upon the mixing board and 9 buckets of cement spread over it. This was then turned with shovels until thoroughly mixed, after which 36 buckets of stone, having been thoroughly dampened, was spread over it and the whole mass turned several times. When the mass was well mixed, enough water was added to produce a rather wet mixture and the entire mass turned until of uniform appearance.

(e) Steel.- All of the steel used in the spiral reinforced columns was furnished by the American System of Reinforcing for Concrete Construction of Chicago. It was all high-carbon steel and was in four sizes; 1/4, 3/8, 7/16, and 1/2 in.

2. Test Specimens.- The conditions of fabrication of the test specimens were kept as uniform as possible. Generally a sufficient amount of concrete to make one column and the auxiliary specimens only was mixed. Never was there more than enough material for two columns and auxiliary specimens mixed in the same batch.

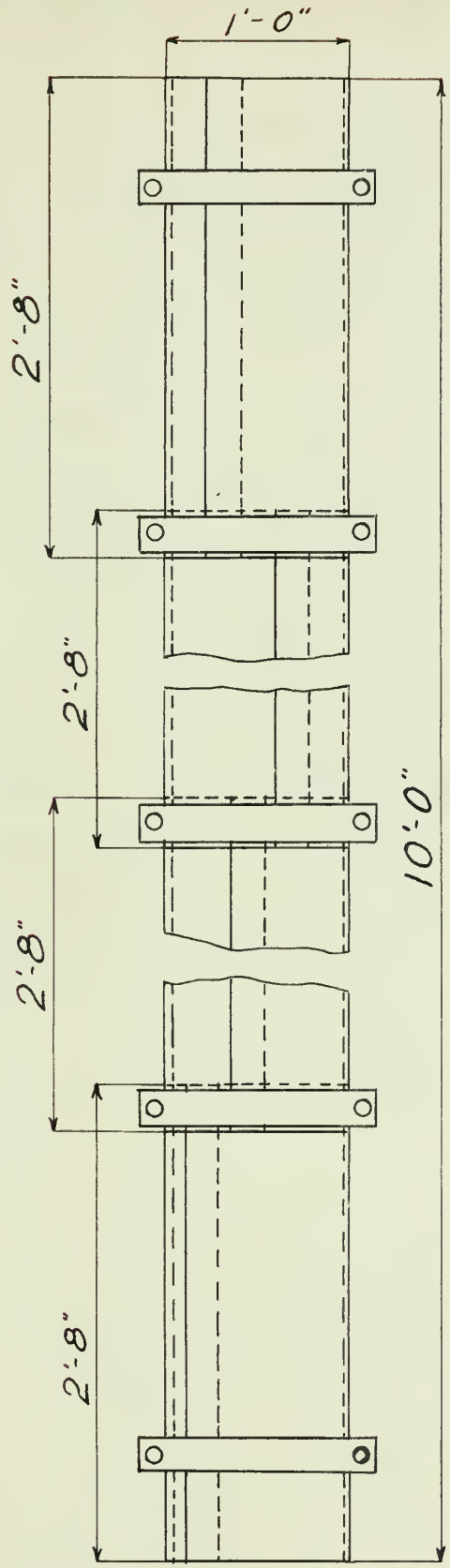
The auxiliary specimens consisted of 6-in. and 12-in. cubes of which only the former have been tested. Three 6-in. cubes were always made first from each batch but if the quantity of concrete appeared to be insufficient for the columns and twelve inch cubes, the latter were not made until after the column, and sometimes not at all. The purpose of the auxiliary specimens was to indicate the quality of the concrete.

(a) Columns.- The mixture used throughout was a 1-2-4 mixture.

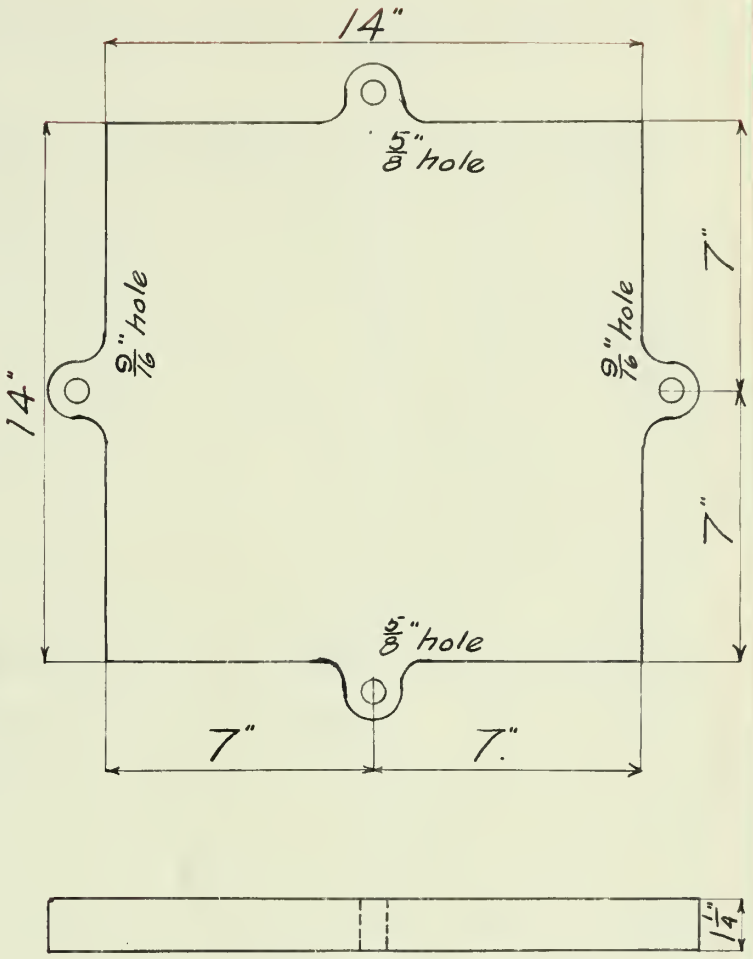
The reinforcement in 13 columns consisted of a single wire of high-carbon steel 1/4 in. in diameter, coiled in the form of a helix with a pitch of one inch. The pitch was held constant by the use of three light steel ties running longitudinally. The reinforcement in the remaining 9 columns was similar to the above but varied in regard to size and pitch of wire. Three of these were reinforced by a 3/8-in. spiral with a 2 inch pitch, three by a 7/16-in. spiral with a 3 inch pitch and three by a 1/2-in. spiral with a pitch of 4 inches.

(b) Forms.- The column forms were cylindrical in section, two and one-half feet in length, made of galvanized sheet steel. They were held tight against the spacing bars by means of bolts which were placed on the 1 x 3/16 in. bands which held the forms together. The sections were fitted together in stove pipe fashion, being readily adjusted, and easily removed when the concrete had set. The forms, with dimensions are shown in Fig. 1.

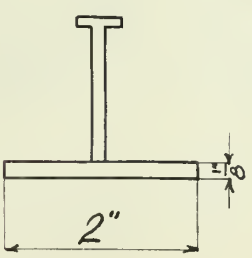
The forms for the six inch cubes were made of steel, three in a set and were held together by bolts and nuts. The



Forms for Columns.



Details of Base Plate.



Details of Nail-Plate.

Fig. 1.

forms for the twelve inch cubes were of the ordinary wooden type. All forms remained in place for from seven to ten days after the material was placed in them.

(c) Making of the Columns.- In making the columns the form was placed around the spiral for the full length of the column, after which it was set up vertically on a castiron base plate with reference to which it was carefully plumbed. The concrete was put in from the top of the form in layers of about 6 inches and tamped or churned until water flushed to the top. The spiral was usually covered by from 1/16 to 1/4 in. of mortar. As this outside coat scaled off early in the test and did not add appreciably to the strength of the column the diameter of the column was assumed to be the same as the outside diameter of the spiral. The surface of several of the columns was rough and pitted, especially at the top and bottom, but taken as a whole, the surface was very good. The top of the column was finished off with a thin layer of cement mortar of the same proportion as used in the concrete of the column.

All of the columns except the 15-ft. and 20-ft. were made on the floor of the testing laboratory and remained in place until ready to be tested, the forms having been removed after 7 days. The 15- and 20-ft. columns were made in the concrete laboratory and brought to the testing laboratory shortly before testing.

The cubes were made in forms as described above, the manner of making being the same as described for the columns.

3. Methods of Testing.- The columns were all tested in a Riehle vertical screw testing machine having a capacity of 600 000 lb. For all of the columns a speed of 0.05 in. per min. was used, the load being applied in increments of about 25000 lb. until the maximum was approached when increments of about 10000 lb. were used. Photograph No. 1 shows a column in the machine after the test.

The cubes were tested in a Rienle testing machine of 100 000 lb. capacity.

Shortly before time for the test a heavy castiron plate (shown in Fig. 1) was placed on the top of the column upon a bed of plaster of paris. This plate was joined to the base plate by iron rods which were screwed up tight enough so that when the column was suspended there was no danger of the column falling out. In order to carry them to the machine the long columns (over 10 ft. long) were placed in a horizontal position on a wagon and hauled to the testing laboratory where they were placed in the testing machine by means of chains and pulleys.

The shorter columns (10 ft. or less in length) having been made on the floor of the testing laboratory were transferred to the machine by means of a system of overhead travelers made of I-beams. As before, the baseplate was joined to the head plate by rods which relieved the upper part of the column of any tension due to the weight.

Photograph No. I.

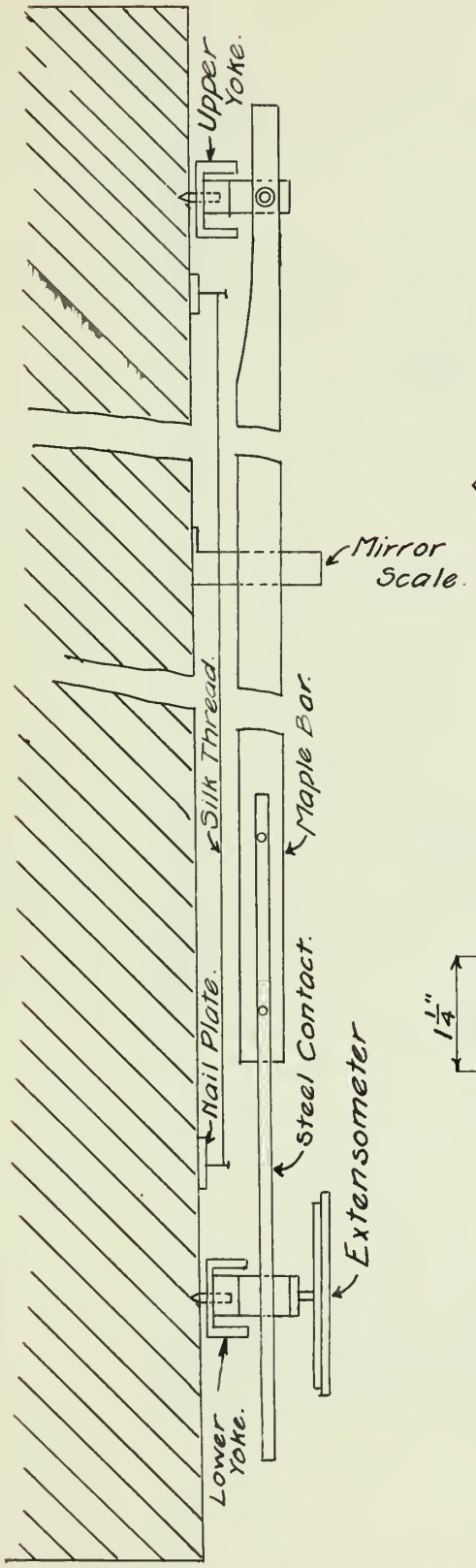
View showing column in machine after test.

The base plate of the machine was cleaned of all sand or cement and the column approximately centered between the screws. If the bearing on the machine bed was uneven a piece of belting was placed beneath the base plate. The head of the machine was then run down and the spherical bearing block accurately centered on the top plate.

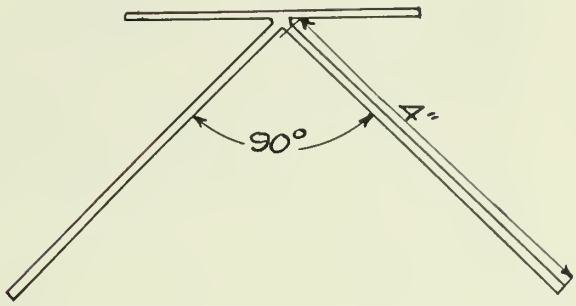
The longitudinal deformation of the column was measured by four extensometers spaced equally distant around the column, thus giving four sets of readings. The lateral deflection or buckling was measured by means of a string fastened at the top and bottom of the column and about 2 inches from the face, readings being taken from scales on mirrors attached at right angles to each other placed at the center of the column, (see Fig. 2). The deflection was read from the scales to hundredths of an inch . By the use of two mirrors at right angles with each other it was possible to obtain deflections in all directions with a single thread.

Fig. 3 shows drawings of the extensometers and of the yokes for fastening them to the columns. The yokes were placed symmetrically about the middle of the length of the column so as to give a gauge length of 100 inches for 10, 15 and 20 foot columns and a gauge length of 40 inches for 5 foot columns.

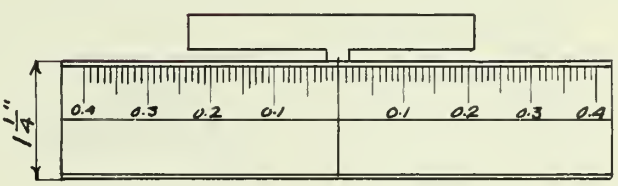
The extensometers recorded the deformation of the column in the following manner. A maple rod 9 ft. 6 in. x 1/2 x 3/4 in., to the lower end of which was fastened a steel contact strip about 12 in. x 1/16 x 5/16 in.,was secured to the upper yoke



Arrangement of Instruments.



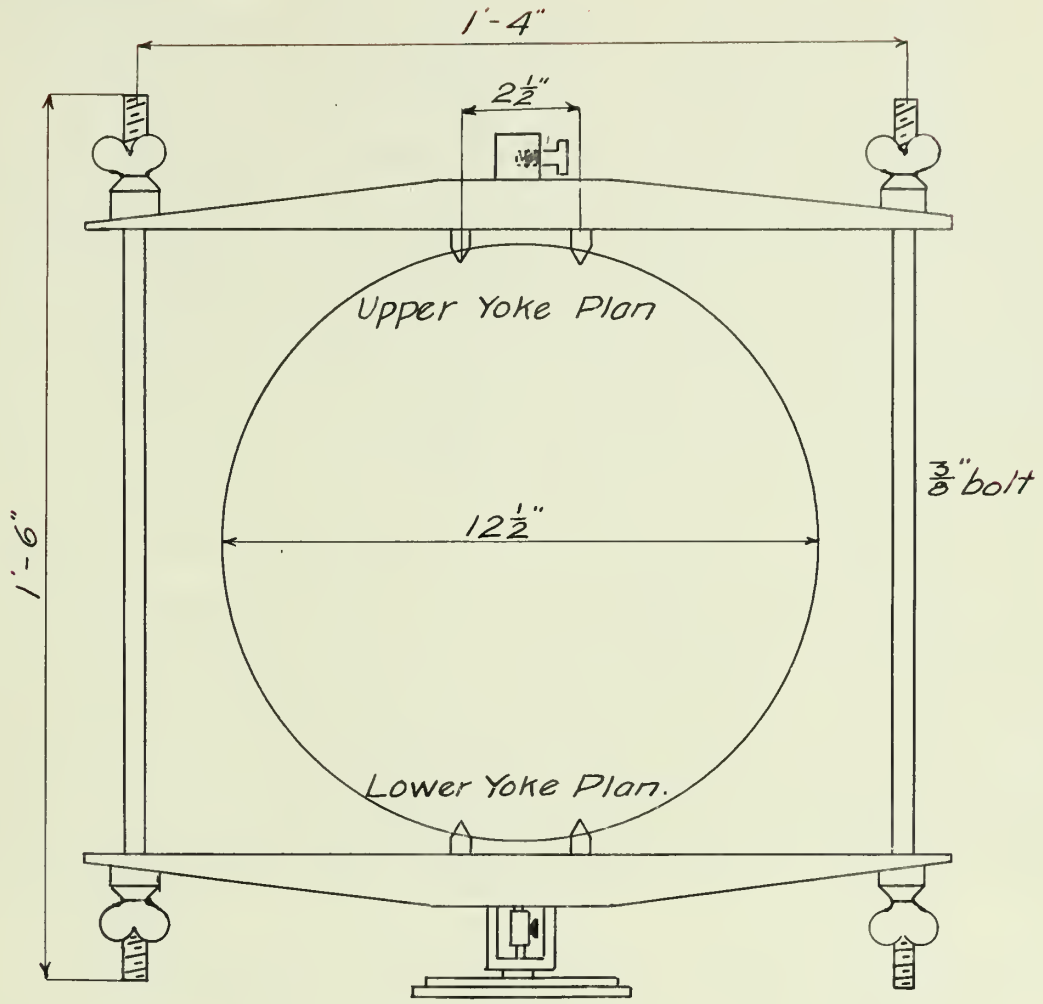
Plan.



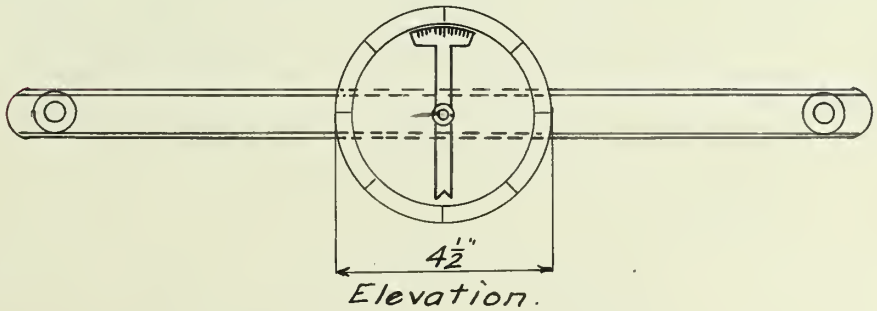
Elevation.

Details of Mirror Scale.

Fig. 2.



Plan.



Elevation.

Extensometer Yokes.

Fig. 3.

by a set screw. The steel contact strip moved on a steel drum 1/2 inch in circumference on the axis of which was fastened a steel pointer. As the column was deformed the drum was rotated by the movement of the contact strip. The pointer passed over a dial which was graduated to thousandths of an inch.
By means of a vernier on the pointer, readings could be taken to ten thousandths of an inch, although this was not done, since the nature of the tests did not warrant so high a degree of accuracy.

The yokes carrying the dials were placed near the bottom of the column where they could be easily read and were spaced about 4 inches apart while the yokes supporting the rods were placed near the top directly over their corresponding dial yoke and 100 inches (or 40 inches for 5 ft. lengths) above them. Good contact on the drum was secured by having one face of the steel rod slightly cylindrical while rubber bands held it tightly on the drum.

In taking the deformations the machine was stopped at each load while the instruments were read. Four men were usually employed in making the tests. One man ran the machine, two men read the extensometers, while the fourth recorded the data in a field book.

Table 5.

Summary of Tests of Spiral-hooped Columns.

Col. No.	Length ft.	Length in.	Age at Test days	Reinforcement Pitch in.	Reinforcement Size in.	Reinforcement Section sq.in.	Reinforcement Per cent	Maximum Load Total lb.	Maximum Load lb. per sq. in.
6	5	2	87	1	¼	.049	1.65	524 900	4640
16	5	2	77	1	¼	.049	1.65	546 000	4830
24	5	1½	62	1	¼	.049	1.65	517 700	4790
3	10	2⅝	92	1	¼	.049	1.65	438 000	3880
17	10	2½	77	1	¼	.049	1.65	434 000	3840
28	10	2¼	62	1	¼	.049	1.64	415 500	3850
7	10	2⅜	86	1	¼	.049	1.65	378 400	3350
13	15	1⅜	87	1	¼	.049	1.65	315 000	2790
15	15	3	81	1	¼	.049	1.65	327 000	2895
21	15	3	69	1	¼	.049	1.65	388 000	3700
14	19	8 3/8	88	1	¼	.049	1.65	242 000	2140
19	19	9	77	1	¼	.049	1.65	275 000	2540
23	19	7½	63	1	¼	.049	1.65	222 000	1965
4	10	0½	88	2	3/8	.111	1.84	467 000	4130
41	10	3½	61	2	3/8	.111	1.84	323 000	2930
20	10	2½	71	2	3/8	.111	1.83	383 400	3440
43	10	4	58	3	7/16	.150	1.58	294 300	2550
49	10	2⅜	65	3	7/16	.150	1.60	313 000	2720
53	10	3	63	3	7/16	.150	1.60	221 500	1950
27	10	0	63	4	½	.196	1.48	327 400	2550
38	10	4	66	4	½	.196	1.52	314 000	2580
57	10	4	59	4	½	.196	1.53	227 000	1890

III. EXPERIMENTAL DATA AND DISCUSSION.

1. Classification.- There are twenty-two columns described in this thesis. All of these were approximately 12 inches in diameter, center to center of spiral and ranged from approximately 5 feet to 20 feet in length. A summary of the columns is seen in Table 5.

For the purpose of making comparisons between the columns the following classification will be made. The mixture is the same in each case, the conditions governing the two purposes of the tests being the length of the column and the pitch of the spiral. Those columns tested to show the effect of length will be called Group I, while those to show the effect of pitch will be called Group II. The two classes will be divided into sub-groups governed by the length and pitch.

Sub-group I_a, 5 ft. columns, $\frac{1}{4}$-in. spiral, 1 in. pitch.
Sub-group I_b, 10 ft. columns, $\frac{1}{4}$-in. spiral, 1 in. pitch.
Sub-group I_c, 15 ft. columns, $\frac{1}{4}$-in. spiral, 1 in. pitch.
Sub-group I_d, 20 ft. columns, $\frac{1}{4}$-in. spiral, 1 in. pitch.

Sub-group II_a, 10 ft. columns, 1/4 in. spiral, 1 in. pitch.
Sub-group II_b, 10 ft. columns, 3/8 in. spiral, 2 in. pitch.
Sub-group II_c, 10 ft. columns, 7/16 in. spiral, 3 in. pitch.
Sub-group II_d, 10 ft. columns, 1/2 in. spiral, 4 in. pitch.

Sub-group II_a is identical with sub-group I_b as no other 10 ft. columns were made.

2. Failure of Columns.- In nearly all of the columns the failure was not by direct crushing as in the case of plain concrete for there was usually a large lateral deflection. The deflection in general increased with increase in the pitch of the spiral. The column acted in the early part of the test much as a plain concrete column but at about the load that would cause failure in a plain column the spacing bars began to buckle and the layer of concrete outside of the reinforcement began to scale off. As the load was applied beyond this point the deflection and deformation of the column became more noticeable, the shortening ranging from 0.2 in. to 1½ in. The deflection for all of the long columns was greater than for the short columns although the maximum unit stress was much less.

The lateral deflection was usually apparent in all of the columns at the maximum load although in the 5 foot ones it was so to a much less degree than in the longer ones. In at least one column the deflection was as great as 5 inches, but this was considerably beyond the maximum load. The failure was never sudden, although the highly stressed condition of the column was evidenced by the scaling of the outer concrete, the buckling of the spacing bars and in some cases the bursting of the spiral hoops with crushing of the concrete inside of the hooping. The bursting of the hoops occurred only at or beyond the maximum load and near the top of the column.

Photograph No. II shows a typical failure of a 20 foot column and Photograph No III shows a typical failure of a 10 ft. column. In these the lateral deflection is plainly seen while in Photograph No. III the scaling of the surface and buckling of the spacing bars are very apparent. Photograph No. IV shows a closer view of the scaled surface and also 3 spiral hoops broken near the top.

3. Effect of Length on Strength.- The effect of the length of a column on the strength where the mixture, the percent reinforcement, size and pitch of the spiral are the same is shown by the diagram in Fig. 4. For this purpose the columns of Group I were tested. The curve was plotted using the maximum unit stress as ordinates and the length as abscissae. The maximum was plotted for each column and a curve drawn through the average for each length.

It is natural to suppose that the strength of a column depends on the length and the curve shows this. However, the curve cannot be taken as directly true except for the values given, since the curve, if produced, shows that a column approximately 35 feet in length would have no strength whatever.

But the average curve as drawn may be taken as showing the general characteristics and effect of length on the strength, that is, the strength of spirally reinforced columns varies with the length and the shorter the column the greater will be the maximum unit stress within limits.

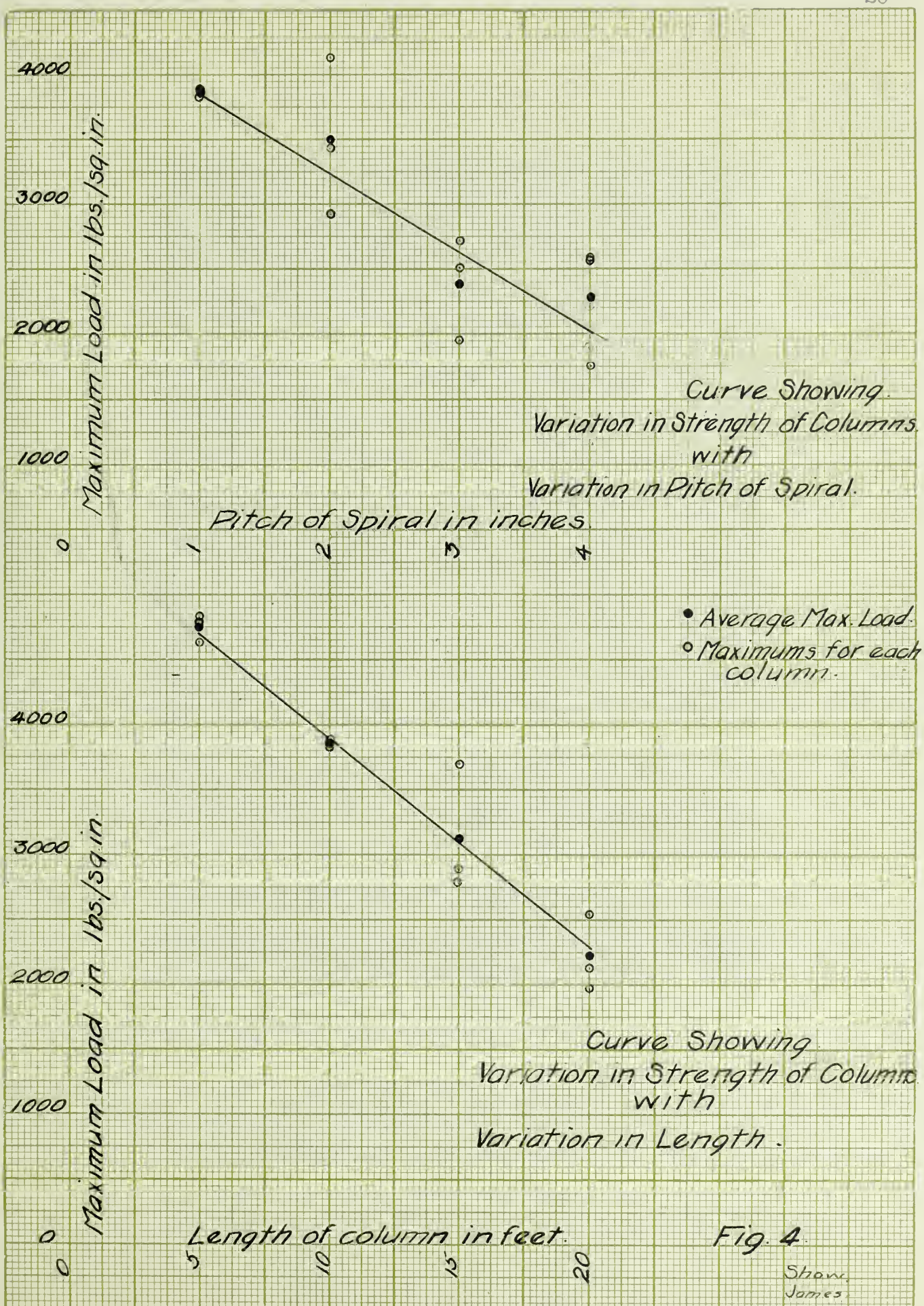


Fig. 4.

Shows James

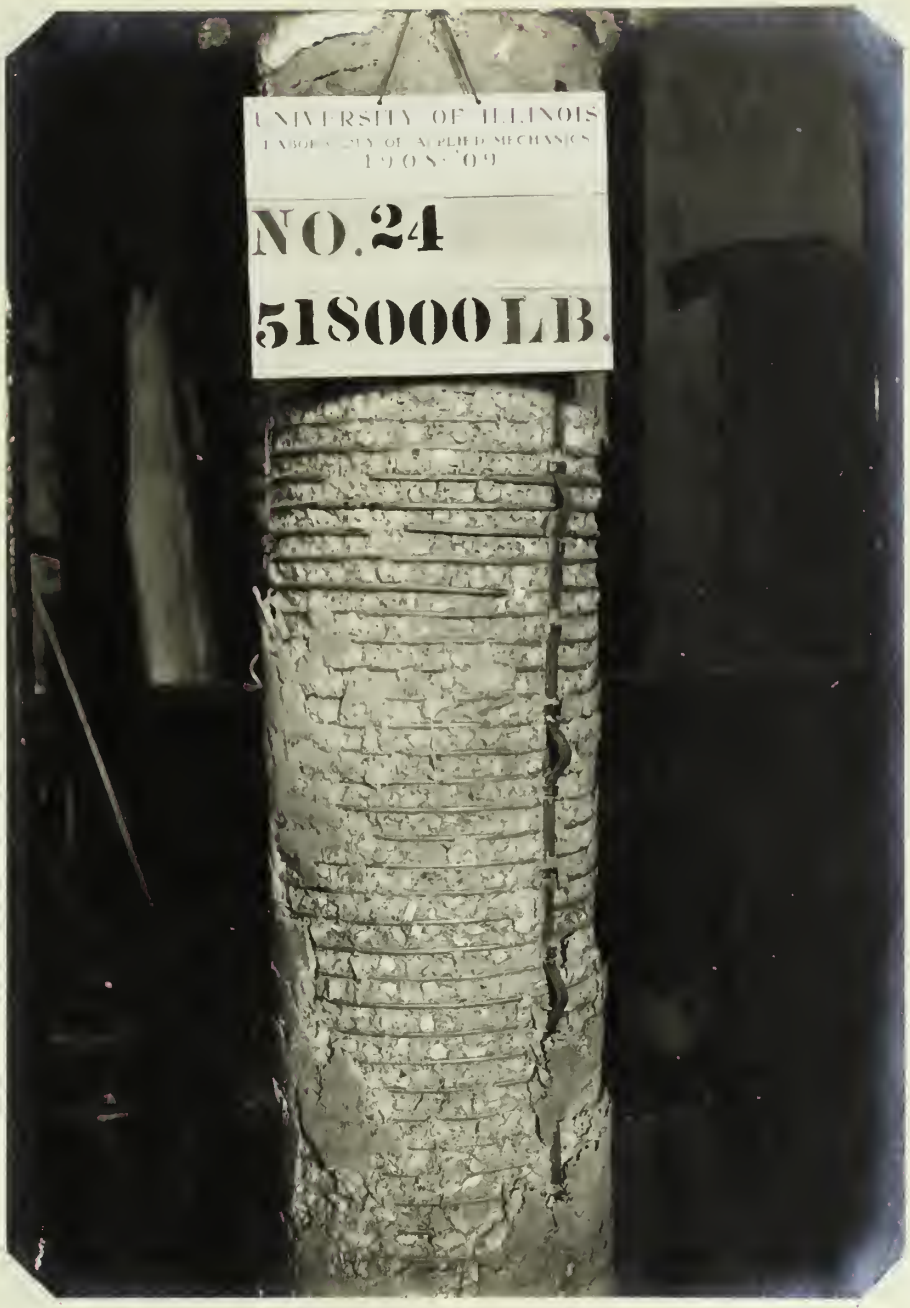
EUGENE DIETZGEN CO., CHICAGO.

Photograph No. II.

View showing a typical failure of 20 ft. column.

Photograph No. III.

View showing a typical failure of 10 ft. column.



Photograph No. IV.

View showing scaling of surface and broken spiral hoops.

From Table 6 it is seen that the additional strength of a column per 1% of reinforcement varies with the length, the shorter columns of the same mixture and percent reinforcement having a greater additional strength than the longer ones. This table also shows that the stiffness of the column decreases as the length increases.

4. Effect of Pitch.- For this test the columns of Group II were used. The mixture and the length were the same in all these columns while the percentage of reinforcement was approximately the same, the only variable being the pitch of the spiral which ranged from 1 to 4 inches. The curve in Fig. IV shows the variation of strength with pitch. This curve was plotted in the same manner as the curve to show the effect of length on strength, maximum unit stresses being used as ordinates and pitch in inches as abscissae. The curve is an average curve and theoretically should not intersect the axis, although the curve as plotted is a straight line curve and will intersect.

Table 6 shows that as the pitch of the spiral increases the additional strength per 1% reinforcement decreases. This table also shows that as the pitch of the spiral increases the strength of the column decreases.

Table 6.

Properties of Spiral-hooped Columns.

All columns made of 1-2-4 concrete

Col. No.	Length ft.	Length in.	Spiral Size inches	Spiral Pitch inches	Strength of Column lb.per sq.in. Concrete from Diagram	Strength of Column lb.per sq.in. Maximum.	Additional Strength per 1% reinforcement. lb.per sq.in.	E'	Initial Modulus of Elasticity.	E"
				Percent Reinforcement = 1.65						
6	5	2	1/4	1	1225	4640	2070	.0006	3600000	.0051
16	5	2	1/4	1	1325	4830	2120	.0008	3875000	.00418
24	5	1 1/2	1/4	1	1350	4790	2080	.000505	3800000	.00363
Av.					1300	4750	2090	.000635	3759000	.0043
3	10	2 1/2	1/4	1	2000	3880	1140	.001	4375000	.00402
17	10	2 1/2	1/4	1	2000	3840	1120	.00103	5500000	.0058
28	10	2 1/4	1/4	1	2475	3850	834	.0014	5050000	.00423
7	10	2 3/4	1/4	1	1325	3350	1230	.00075	5050000	.00495
Av.					1950	3730	1081	.00104	4994000	.00475
13	15	1 3/4	1/4	1	2125	2790	403	.00135	3875000	.0029
15	15	3	1/4	1	1990	2930	570	.00115	4375000	.003
21	15	3	1/4	1	2025	3700	1020	.00105	4225000	.0057
Av.					2046	3140	664	.00118	4158000	.0039
14	19	8 3/8	1/4	1	1450	2480	625	.00055	4525000	.00155
19	19	9	1/4	1	1100	2540	872	.00027	5100000	.00125
23	19	7 1/2	1/4	1	1630	1965	185	.00115	3375000	.00183
Av.					1400	2330	561	.00065	4333000	.00154
				Columns 10 ft. in Length.						
	Percent Rein.									
4	1.84		3/8	2	2250	4130	1021	.0015	7000000	.00595
41	1.84		3/8	2	1360	2930	854	.00095	4450000	.0097
20	1.83		3/8	2	1950	3440	815	.0015	3750000	.0091
Av.					2190	3500	897	.00131	5066000	.00825
43	1.58		7/16	3	1330	2500	740	.001	3475000	.00187
49	1.60		7/16	3	1500	2720	656	.00143	2650000	.0040
53	1.60		7/16	3	900	1950	656	.00125	1500000	.0057
Av.					1240	2390	684	.00123	3541600	.00386
27	1.48		1/2	4	2000	2555	375	.0016	5600000	.00535
36	1.52		1/2	4	1550	2580	677	.0011	4150000	.0088
57	1.53		1/2	4	950	1890	990	.0012	1775000	.006
Av.					1500	2295	664	.0013	3841000	.00671

5. Efficiency of Reinforcement.- In the discussion which follows, the columns will be referred to according to the classification which is given on page 17.

A close inspection of the stress deformation diagram shows that the curves, during the early part of the test, are fairly uniform, the form being approximately that of a parabola. But as the stress increases the curves take a decided bend and then continues on a comparatively straight line.

Prof. A. N. Talbot states in Bulletin No. 20 of the Engineering Experiment Station that the deformation at this point corresponds very closely with the ultimate deformation found in plain concrete columns. Column No. 5 headed "concrete from diagrams", Table 6, is based upon this assumption and a comparison of this column with column No. 7 headed "lb. per sq. in.", Table 7, gives a rough check on this assumption.

The method of finding the point where the curves take a decided bend is as follows: At the point where the curve makes the decided change, the radius of curvature will be very short in comparison with the radius at any other point. Therefore, if perpendiculars be drawn to the tangent of the curve at two points close together, their intersection will be approximately at the center of curvature for the part of the curve considered and the shortest radius thus found will locate the point where the concrete began to fail and the steel began to take the stress. These values for the different curves are given in column No. 3 of Table 6, while the unit deformation for this load is given in

column No. 6 of the same table under the head of E'. Column No.8 gives the maximum unit deformation

The difference between column No. 3 and column No. 4 gives the additional strength due to the reinforcement and this difference divided by the percent of reinforcement gives the additional strength for each 1% reinforcement which is found in column No. 5.

The average for the estimated strength of plain concrete for the 10-ft. columns is somewhat greater than the average obtained from the tests of three 10-ft. control columns which were broken in connection with this series.. Table 8 gives a comparison of these tests with the estimated strength of the 10-ft. columns. Some of the variations in strength is no doubt due to the variation in age of the different test specimens.

Taking the strength of plain concrete as that obtained by the approximate method explained on page 26 and shown in column No. 4 of Table 6, it is seen that the efficiency of the reinforcement decreases as either the length of the column or the pitch of the spiral increases.

For the percent of reinforcement in the columns, the outside diameter of the spiral helix was taken rather than the diameter center to center of the wire. The percent was obtained by assuming that the helix is converted into a cylinder having the same amount of steel and the same mean diameter as the helix actually used. The ratio of the area of steel to that of the concrete core, when cut by a plane at right angles to the axis of the column, is considered the percent of reinforcement. This

gives rise to the following formula:

$$p = \frac{\pi \times D \times a}{P \times A}$$

in which

p = percent of reinforcement

D = outside diameter of spiral helix

a = cross sectional area of wire of which helix is made

P = pitch of spiral

A = cross sectional area of column using D as diameter.

6. Initial Modulus of Elasticity.- The initial modulus of elasticity as shown in column No. 8 of Table 6 was obtained by drawing a tangent to the curve at the zero point, the tangent of the angle which this line makes with the axis of abscissae being the modulus desired. An average of all values gives as a modulus, 4 135 000 lb. per sq. in. This is considerably higher than the value obtained in 1908 by Messrs. Gonnerman, Slaymaker and Weber for a 1-2-4 mixture, their value being 3 509 000 lb. per sq. in.

7. Tests of Cubes.- Table 7 gives the results of the 6-in. cube test with the age at testing, each value being the average of three tests. The 12-in. cubes were not tested for use in this thesis.

For the purpose of comparison, Table 7 also gives the results of the column tests with age at testing. It was found impossible to test the cubes at exactly the same age at which the columns were tested but the variation was not sufficient to

seriously affect a comparison as to the quality of the concrete. It was not the purpose in testing the cubes to give a direct comparison in strength of the concrete but simply show the quality of it.

8. Stress-deformation Diagrams.- The diagrams on pages 43 to 65 inclusively, show the stress-deformation curves for the columns tested. The data from which these curves were plotted can be found on pages 32 to 43 inclusively. The unit load was, in most cases, computed using the diameter outside the reinforcement less the diameter of the spiral as the effective diameter of the column. In some cases, however, the actual diameter of the column was not measured and 12 inches was then taken as the effective diameter.

The readings of the four extensometers were first plotted separately, using the total load and total deformation as ordinates and abscissae respectively. From these curves the deformations to be used in obtaining the mean were selected, since the curves plainly showed where the instruments had slipped and other accidents had occurred which warranted the exclusion of certain values.

Table 7.

Comparison of Tests of 6-in. Cubes and Columns.

Col. No.	Length ft.	Length in.	Spiral Size inches	Spiral Pitch inches	Cubes Age at Test days	Cubes Maximum Load Total lb.	Cubes Maximum Load lb.per sq.in.	Columns Age at Test days	Columns Maximum Load Total lb.	Columns Maximum Load lb.per sq.in.
6	5	2	1/4	1	96	81 000	2245	87	524 900	4640
16	5	2	1/4	1	119	83 500	2320	77	546 000	4830
24	5	1 1/3	1/4	1	65	78 100	2166	62	517 700	4790
3	10	2 1/3	1/4	1	107	97 600	2710	92	438 000	3880
17	10	2 1/2	1/4	1	119	83 500	2320	77	434 000	3840
28	10	2 1/4	1/4	1	63	99 700	2773	62	415 500	3850
7	10	2 3/4	1/4	1	99	105 800	2935	86	378 400	3350
13	15	1 3/4	1/4	1	101	88 200	2443	87	315 000	2790
15	15	3	1/4	1	87	91 300	2537	81	327 000	2895
21	15	3	1/4	1	71	91 800	2546	69	388 000	3700
14	19	8 3/8	1/4	1	96	101 600	2820	88	242 000	2140
19	19	9	1/4	1	76	75 600	2100	77	275 000	2540
23	19	7 1/2	1/4	1	63	97 700	2715	63	222 000	1965
4	10	0 1/2	3/8	2	103	113 500	3150	88	467 000	4130
41	10	3 1/3	3/8	2	72	96 600	2682	61	323 500	2930
20	10	2 1/2	3/8	2	109	90 300	2507	71	383 400	3440
43	10	4	7/16	3	60	76 500	2124	58	294 300	2500
49	10	2 3/4	7/16	3	70	84 600	2343	65	313 000	2720
53	10	3	7/16	3	73	67 500	1876	63	221 500	1950
27	10	1 1/2	1/2	4	63	76 200	2118	63	327 400	2555
36	10	4	1/2	4	63	80 400	2233	66	314 000	2580
57	10	4	1/2	4	66	61 100	1696	59	227 000	1890

Table 8.

Comparison of Estimated Strength of Concrete in Reinforced Concrete with Strength in Plain Concrete Columns

Group	Col.No.	Age at Test days		Estimated Ultimate Stress in Concrete lb. per sq. in.
I_b	3	92		2000
	17	77		2000
	28	62		2475
	7	86		1325
			Av.	1950
II_b	4	88		2250
	41	61		1360
	20	71		1950
			Av.	1853
II_c	43	58		1300
	49	65		1500
	53	63		900
			Av.	1233
II_d	27	63		2000
	36	66		1550
	57	59		950
			Av.	1500
Control	26	66		1625
	35	65		1360
	39	65		1620
			Av.	1521

IV. SUMMARY.

The following conclusions can be drawn from the results of the foregoing tests:

1. The failure of spiral-hooped columns is always preceded by a spalling of the concrete outside the steel. The approach of failure is also signified by a lateral bending which is very marked in long columns but decreases to an almost inappreciable amount in the short ones.

2. The ultimate strength of spiral-hooped columns decreases rapidly as the length increases. The effect of length on stiffness is much the same as the effect on strength, the stiffness decreasing as the length increases.

3. The effect of increasing the pitch of the spiral with which the column is reinforced is to decrease both the ultimate strength and the stiffness of the column.

4. The efficiency of reinforcement, as shown by the approximate additional strength per 1% of reinforcement, decreases with the increase in the length of the column. The efficiency also decreases with an increase in the pitch of the spiral.

Column No. 6.

Total Load. lb.	Unit Stress lb. per sq. in.	Unit Deformation
6 500	60	0.00000
26 000	230	0.00006
52 000	460	0.00013
75 000	660	0.00022
101 000	900	0.00034
126 000	1120	0.00050
150 000	1330	0.00073
175 000	1550	0.00110
200 000	1770	0.00159
225 000	1990	0.00217
250 000	2220	0.00302
275 000	2440	0.00380
300 000	2660	0.00508
325 000	2880	
350 000	3100	
375 000	3320	
400 000	3540	
425 000	3760	
524 900	4640	

Age, 87 days
$\frac{1}{4}$-in. spiral
1 in. pitch
Length, 5 ft. 2 in.
Diameter, 12 in.
Area, 113 sq. in.

Col. No. 16.

Total Load lb.	Unit Stress lb. per sq. in.	Unit Deformation
6 400	60	0.00000
26 000	230	0.00006
51 000	450	0.00013
75 000	660	0.00021
100 000	890	0.00029
125 000	1110	0.00049
150 000	1330	0.00080
175 000	1550	0.00132
200 000	1770	0.00214
225 000	1990	0.00312
250 000	2210	0.00417
260 000	2300	
275 000	2440	
300 000	2650	
325 000	2870	
350 000	3100	
546 000	4830	

Age, 77 days
$\frac{1}{4}$-in. spiral
1 in. pitch
Length, 5 ft. 2 in.
Diameter, 12 in.
Area, 113 sq. in.

Col. No. 24.

Total Load. lb.	Unit Stress lb. per sq. in.	Unit Deformation
6 200	.60	0.00000
26 000	240	0.00004
51 000	470	0.00009
77 000	710	0.00019
102 000	940	0.00031
126 000	1170	0.00037
151 000	1400	0.00058
175 000	1620	0.00085
200 000	1850	0.00108
225 000	2080	0.00152
250 000	2310	0.00212
275 000	2550	0.00281
300 000	2780	0.00363
325 000	3010	0.00408
375 000	3470	
400 000	3700	0.00539
425 000	3930	0.00613
450 000	4160	0.00812
475 000	4400	0.00800
500 000	4630	
510 000	4720	
514 000	4750	
515 400	4770	
517 300	4790	
517 700	4790	

Age, 62 days.
$\frac{1}{4}$-in. spiral
1 in. pitch.
Length, 5 ft. $1\frac{1}{2}$ in.
Diameter, 11.775 in.
Area, 109 sq. in.

Col. No. 3.

Total Load. lb.	Unit Stress lb. per sq. in.	Unit Deformation
6 500	60	0.00000
26 000	230	0.00004
51 000	450	0.00011
77 000	680	0.00018
100 000	890	0.00026
125 000	1110	0.00035
150 000	1330	0.00049
175 000	1550	0.00059
200 000	1770	0.00077
225 000	1990	0.00100
250 000	2220	0.00137
275 000	2440	0.00184
300 000	2660	0.00240
325 000	2880	0.00315
350 000	3100	0.00402
375 000	3320	
400 000	3540	
438 000	3880	

Age, 92 days
$\frac{1}{4}$-in. spiral
1 in. pitch
Length, 10 ft. $2\frac{1}{2}$ in.
Diameter, 12 in.
Area, 113 sq. in.

Col. No. 17.			Col. No. 28.		
Total Load. lb.	Unit Stress lb. per sq. in.	Unit Deformation	Total Load. lb.	Unit Stress lb. per sq. in.	Unit Deformation
6 400	60	0.00000	6 500	60	0.00000
27 000	240	0.00005	26 000	240	0.00003
52 000	460	0.00011	51 000	470	0.00010
77 000	680	0.00018	77 000	710	0.00017
102 000	900	0.00026	98 000	910	0.00025
125 000	1110	0.00034	126 000	1170	0.00035
150 000	1330	0.00045	151 000	1400	0.00047
175 000	1550	0.00059	201 000	1860	0.00073
200 000	1770	0.00077	225 000	2090	0.00094
225 000	1990	0.00103	250 000	2320	0.00122
245 000	2170		276 000	2560	0.00152
250 000	2210	0.00146	300 000	2780	0.00196
275 000	2440	0.00208	320 000	2960	0.00256
300 000	2660	0.00296	335 000	3100	0.00301
308 000	2730		350 000	3240	0.00361
325 000	2880	0.00396	365 000	3380	0.00421
350 000	3100	0.00509	380 000	3520	
375 000	3320		400 000	3700	
400 000	3540		413 000	3830	
410 000	3630		414 500	3840	
434 000	3840		415 500	3850	
			411 000	3810	
			405 000	3750	
			396 000	3670	

Age, 77 days
$\frac{1}{4}$—in. spiral
1 in. pitch
Length, 10 ft $2\frac{1}{2}$ in.
Diameter, 12 in.
Area, 113 sq. in.

Age, 62 days
$\frac{1}{4}$—in. spiral
1 in. pitch
Length, 10 ft. $2\frac{1}{4}$ in.
Diameter, 11.73 in.
Area, 108 sq. in.

Col. No. 13.

Total Load lb.	Unit Stress lb. per sq. in.	Unit Deformation
7 600	70	0.00000
20 500	180	0.00004
57 000	510	0.00014
70 500	630	0.00019
86 000	760	0.00024
101 000	900	0.00030
116 000	1030	0.00038
132 000	1170	0.00046
150 000	1330	0.00056
165 000	1460	0.00067
180 000	1590	0.00079
190 000	1680	0.00083
200 000	1770	0.00091
210 000	1860	0.00101
220 000	1950	0.00112
230 000	2040	0.00116
242 000	2140	0.00136
255 000	2260	0.00165
266 000	2360	0.00198
290 000	2570	0.00291
315 000	2990	

Age, 87 days
$\frac{1}{4}$-in. spiral
1 in. pitch
Length, 15 ft. $1\frac{3}{4}$ in.
Diameter, 12 in.
Area, 113 sq. in.

Col. No. 15

Total Load. lb.	Unit Stress lb. per sq. in.	Unit Deformation
8 200	70	0.00000
26 000	230	0.00004
51 000	450	0.00010
75 000	660	0.00018
100 000	890	0.00026
125 000	1110	0.00037
150 000	1330	0.00049
175 000	1550	0.00064
200 000	1770	0.00085
225 000	1990	0.00117
250 000	2220	0.00161
275 000	2440	0.00216
300 000	2660	0.00301
325 000	2880	
331 000	2930	
317 000	2810	
327 000	2900	

Age, 81 days
$\frac{1}{4}$-in. spiral
1 in. pitch
Length, 15 ft. 3 in.
Diameter, 12 in.
113 sq. in.

Col. No. 21.			Col. No. 14		
Total Load. lb.	Unit Stress lb. per sq. in.	Unit Deformation	Total Load. lb.	Unit Stress lb. per sq. in.	Unit Deformation
7 800	70	0.00000	7 500	70	0.00000
26 000	250	0.00004	26 000	230	0.00003
51 000	490	0.00011	51 000	450	0.00009
76 000	720	0.00018	76 000	670	0.00017
100 000	950	0.00027	101 000	900	0.00025
125 000	1190	0.00037	125 000	1110	0.00035
150 000	1430	0.00050	150 000	1330	0.00047
175 000	1670	0.00066	175 000	1550	0.00063
200 000	1910	0.00092	200 000	1770	0.00083
225 000	2140	0.00117	225 000	1990	0.00114
250 000	2380	0.00157	250 000	2210	0.00154
275 000	2620	0.00221	270 000	2480	
300 000	2860	0.00282	222 000	1970	
325 000	3100	0.00360	242 000	2140	
350 000	3340	0.00457			
375 000	3570	0.00572			
388 800	3700				

Age, 69 days
$\frac{1}{4}$-in. spiral
1 in. pitch
Length, 15 ft. 3 in.
Diameter, 11.68 in.
Area, 107 sq. in.

Age, 88 days
$\frac{1}{4}$-in. spiral
1 in. pitch
Length, 19 ft. 8 3/8 in.
Diameter, 12 in.
Area, 113 sq. in.

Col. No. 19.

Total Load. lb.	Unit Stress lb. per sq. in.	Unit Deformation
8 000	70	0.00000
27 000	250	0.00004
51 000	470	0.00009
77 000	710	0.00015
100 000	930	0.00022
126 000	1160	0.00030
150 000	1390	0.00040
175 000	1620	0.00052
200 000	1850	0.00068
225 000	2080	0.00091
250 000	2310	0.00107
275 000	2540	0.00126
255 000	2350	
267 000	2470	
231 000	2140	
255 000	2350	
227 000	2100	
239 000	2210	

Age, 77 days
$\frac{1}{4}$—in. spiral
1 in. pitch
Length, 19 ft. 9 in.
Diameter, 11.77 in.
Area, 108.8 sq. in.

Col. No. 23.

Total Load. lb.	Unit Stress lb. per sq. in.	Unit Deformation
6 300	60	0.00000
25 000	220	0.00006
50 000	440	0.00013
75 000	660	0.00023
100 000	890	0.00036
125 000	1110	0.00052
150 000	1330	0.00072
175 000	1550	0.00099
200 000	1770	0.00127
222 000	1965	0.00182

Age, 63 days
$\frac{1}{4}$—in. spiral
1 in. pitch
Length, 19 ft. 7$\frac{1}{2}$ in.
Diameter, 12 in.
Area, 113 sq. in.

Col. No. 7.

Total Load lb.	Unit Stress lb. per sq. in.	Unit Deformation
6 500	58	0.00000
29 000	257	0.00006
53 000	470	0.00012
75 000	665	0.00022
102 000	900	0.00035
127 000	1125	0.00051
150 000	1330	0.00074
175 000	1550	0.00115
200 000	1770	0.00181
225 000	1990	0.00267
250 000	2215	0.00380
275 000	2435	0.00491
300 000	2660	
325 000	2880	
350 000	3100	
372 000	3300	
378 000	3350	

Age, 86 days
$\frac{1}{4}$-in. spiral
1 in. pitch
Length, 10 ft. $2\frac{3}{4}$ in.
Diameter, 12 in.
Area, 113 sq. in.

Col. No. 4.

Total Load lb.	Unit Stress lb. per sq. in.	Unit Deformation
6 500	57	0.00000
26 000	230	0.00004
50 000	443	0.00007
76 000	670	0.00016
100 000	890	0.00023
126 000	1115	0.00031
149 000	1320	0.00041
175 000	1550	0.00053
198 000	1750	0.00070
210 000	1860	0.00084
230 000	2040	0.00111
254 000	2250	0.00149
274 000	2420	0.00190
305 000	2700	0.00258
330 000	2920	0.00342
350 000	3100	0.00380
376 000	3330	0.00485
400 000	3540	0.00594
425 000	3760	0.00733
476 000	4130	

Age, 88 days
3/8-in. spiral
2 in. pitch
Length, 10 ft. $\frac{1}{2}$ in.
Diameter, 12 in.
Area, 113 sq. in.

Col. No. 41.			Col. No. 20		
Total Load. lb.	Unit Stress lb. per sq. in.	Unit Deformation	Total Load lb.	Unit Stress lb. per sq. in.	Unit Deformation
6 800	60	0.00000	8 000	70	0.00000
26 000	240	0.00004	27 000	240	0.00005
52 000	470	0.00013	52 000	470	0.00011
76 000	690	0.00023	77 000	690	0.00022
101 000	960	0.00038	101 000	910	0.00030
125 000	1130	0.00058	125 000	1120	0.00041
150 000	1360	0.00096	150 000	1350	0.00056
175 000	1590	0.00151	175 000	1570	0.00078
200 000	1810	0.00247	200 000	1790	0.00114
225 000	2040	0.00338	225 000	2020	0.00166
250 000	2260	0.00511	250 000	2240	0.00248
271 000	2460	0.00636	275 000	2470	0.00332
285 000	2580	0.00725	300 000	2690	0.00433
300 000	2720	0.00865	324 000	2910	0.00549
315 000	2850	0.01021	350 000	3140	0.00688
322 000	2920		375 000	3360	0.00797
323 500	2930		383 400	3440	0.00909
315 600	2850		358 000	3190	
270 000	2450				

Age, 61 days
3/8-in. spiral
2 in. pitch
Length, 10 ft. $3\frac{1}{2}$ in.
Diameter, 11.88 in.
Area, 111 sq. in.

Age 71 days
3/8-in. spiral
2 in. pitch
Length, 10 ft. $2\frac{1}{2}$ in.
Diameter, 11.91 in.
Area, 111.5 sq. in.

Col. No. 43.

Total Load. lb.	Unit Stress lb. per sq. in.	Unit Deformation
7 000	60	0.00000
26 000	220	0.00005
51 000	440	0.00013
76 000	650	0.00023
100 000	850	0.00035
125 000	1060	0.00052
150 000	1270	0.00084
175 000	1490	0.00147
187 000	1590	0.00188
200 000	1700	
210 000	1780	
220 000	1870	
230 000	1950	
240 000	2040	
252 000	2140	
265 000	2250	
275 000	2330	
287 000	2440	
290 800	2470	
6 700	60	
294 300	2500	
260 000	2210	

Age, 58 days
7/16-in. spiral
3 in. pitch
Length, 10 ft. 4 in.
Diameter, 12.23 in.
Area, 117.8 sq. in.

Col. No. 49

Total Load. lb.	Unit Stress lb. per sq. in.	Unit Deformation
7 300	60	0.00000
26 000	230	0.00005
51 000	440	0.00015
75 000	650	0.00026
100 000	870	0.00041
125 000	1090	0.00059
150 000	1300	0.00091
175 000	1520	0.00143
200 000	1740	0.00233
220 000	1910	0.00304
240 000	2080	0.00401
260 000	2260	
280 000	2430	
295 000	2560	
298 000	2590	
308 000	2680	
311 000	2700	
313 000	2720	

Age, 65 days
7/16-in. spiral
3 in. pitch
Length, 10 ft. 23 in.
Diameter, 12.11 in.
Area, 115.2 sq. in.

Col. No. 53.			Col. No. 27.		
Total Load. lb.	Unit Stress lb. per sq. in.	Unit Deformation	Total Load. lb.	Unit Stress lb. per sq. in.	Unit Deformation
6 500	60	0.00000	6 500	50	0.00000
26 000	230	0.00012	26 000	200	0.00004
51 000	450	0.00034	52 000	410	0.00010
75 000	660	0.00062	76 000	590	0.00016
100 000	880	0.00111	101 000	790	0.00023
125 000	1100	0.00211	126 000	980	0.00028
150 000	1320	0.00358	150 000	1170	0.00041
162 500	1430	0.00461	175 000	1360	0.00053
175 000	1540	0.00571	200 000	1560	0.00074
182 000	1600		225 000	1750	0.00101
187 500	1650		250 000	1950	0.00145
200 000	1760		275 000	2140	0.00219
210 000	1850		294 000	2290	0.00291
216 000	1900		310 000	2420	0.00386
221 500	1950		322 000	2510	0.00440
220 000	1940		327 000	2550	0.00515
210 000	1850		327 400	2560	0.00536
			321 000	2500	
			312 000	2430	
			292 000	2280	

Age, 63 days
7/16-in. spiral
3 in. pitch
Length, 10 ft. 3 in.
Diameter, 12.04 in.
Area, 113.8 sq. in.

Age, 63 days
½-in. spiral
4 in. pitch
Length, 10 ft. 1½ in.
Diameter, 12.80 in.
Area, 128.5 sq. in.

Col. No. 36.

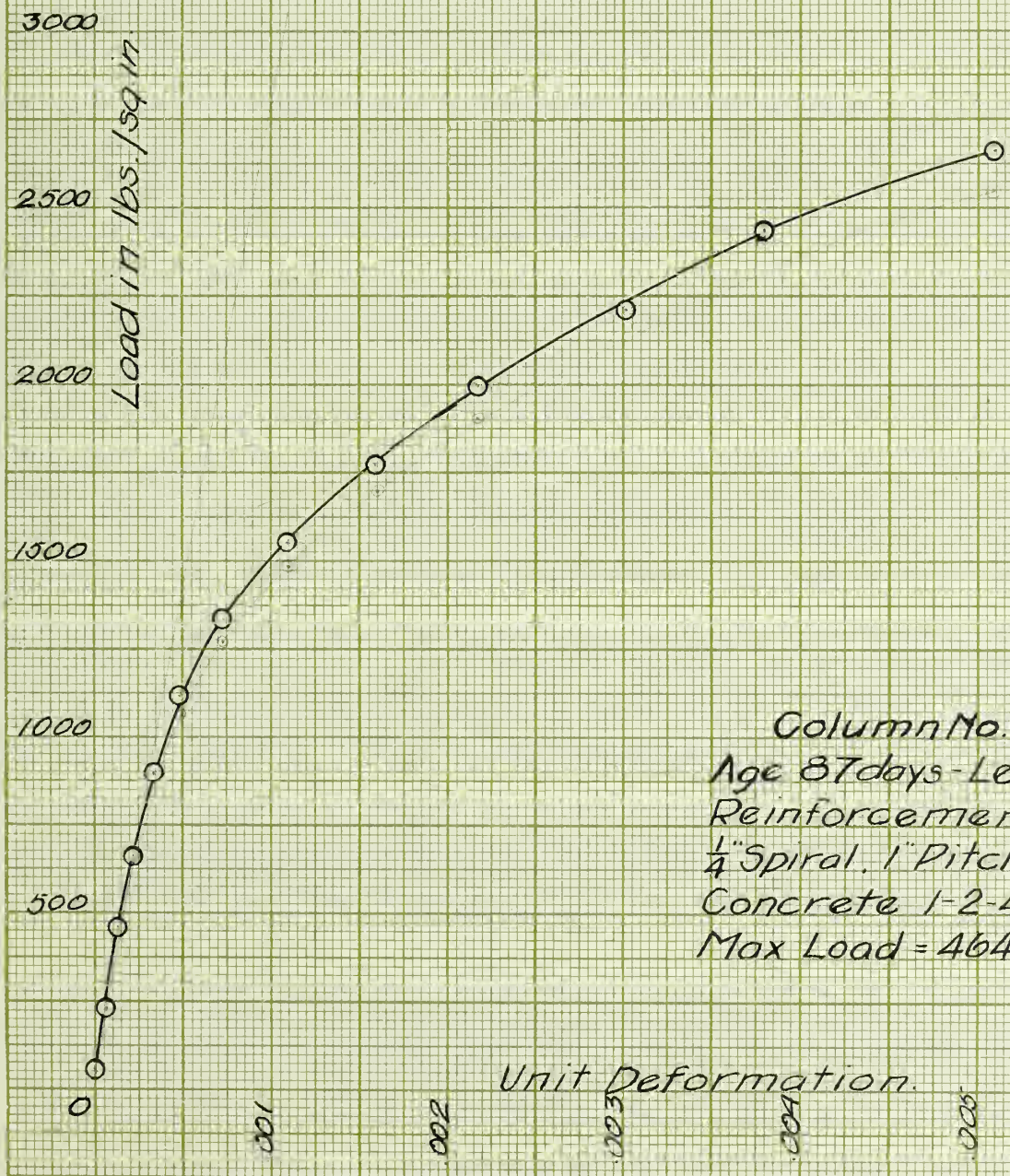
Total Load lb.	Unit Stress lb. per sq. in.	Unit Deformation
7 000	60	0.00000
25 000	210	0.00003
51 000	420	0.00011
75 000	620	0.00019
100 000	820	0.00031
125 000	1030	0.00041
150 000	1230	0.00058
175 000	1440	0.00087
200 000	1640	0.00146
225 000	1850	0.00247
250 000	2050	0.00374
273 000	2240	0.00505
285 000	2340	0.00597
295 000	2420	0.00685
305 000	2500	0.00762
314 000	2580	0.00888
309 000	2530	
290 000	2380	
175 000	1440	

Age, 66 days
½-in. spiral
4 in. pitch
Length, 10 ft. 4 in.
Diameter, 12.48 in.
Area, 122 sq. in.

Col. No. 57.

Total Load. lb.	Unit Stress lb. per sq. in.	Unit Deformation
6 100	50	0.00000
25 000	208	0.00005
50 000	416	0.00025
75 000	625	0.00045
100 000	833	0.00074
125 000	1040	0.00123
150 000	1250	0.00232
175 000	1460	0.00401
185 000	1540	0.00479
196 000	1630	0.00600
205 000	1710	0.00632
215 000	1790	0.00668
220 000	1830	
225 000	1880	
226 000	1880	
227 000	1890	
226 000	1880	
5 800	50	

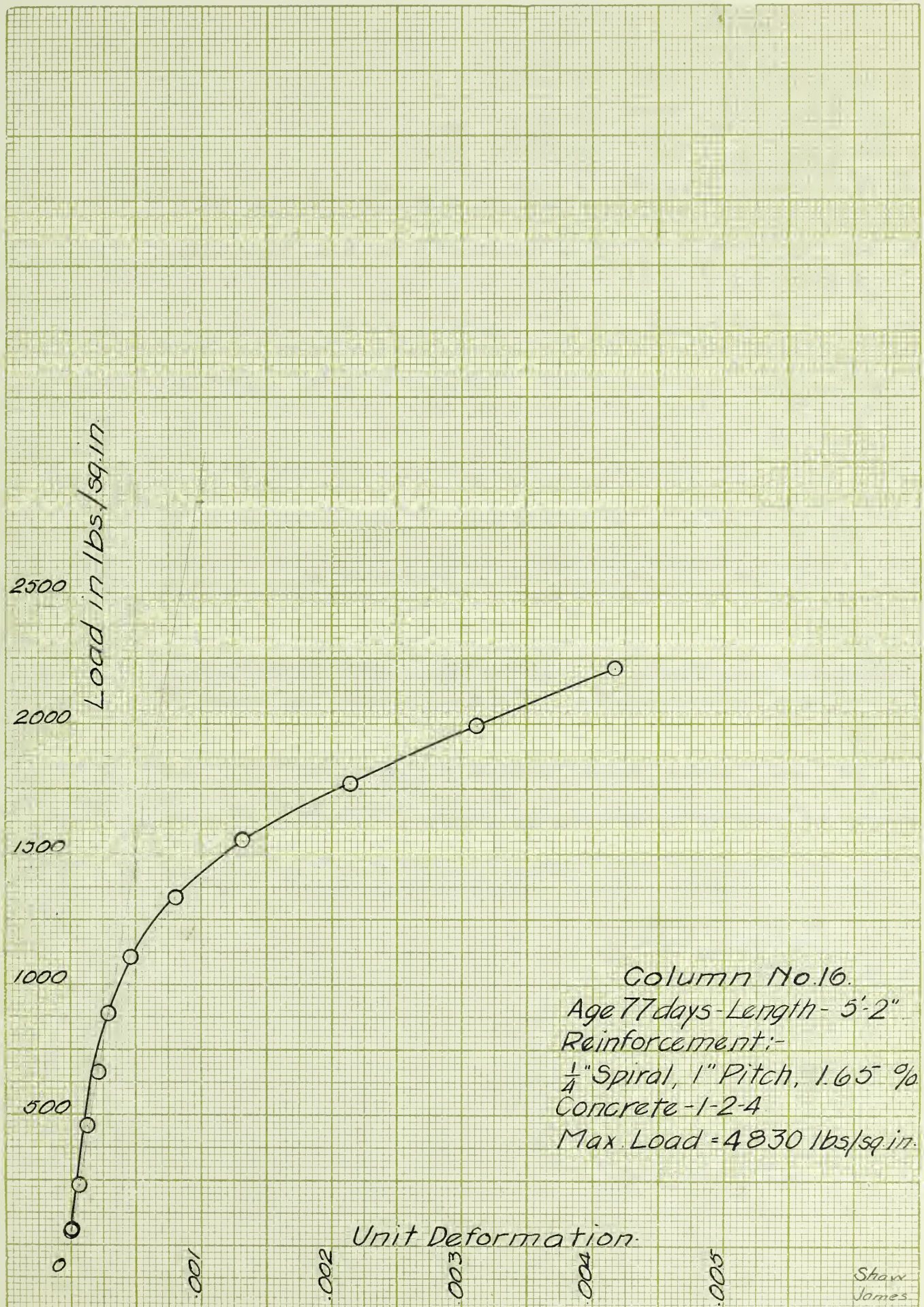
Age, 59 days
½-in. spiral
4 in. pitch
Length, 10 ft. 4 in.
Diameter, 12.36 in.
Area, 120 sq. in.



Column No. 6.
Age 87 days - Length 5'-2".
Reinforcement:-
$\frac{1}{4}$" Spiral. 1" Pitch, 1.65%.
Concrete 1-2-4.
Max Load = 4640 lbs/sq.in.

Shaw
James

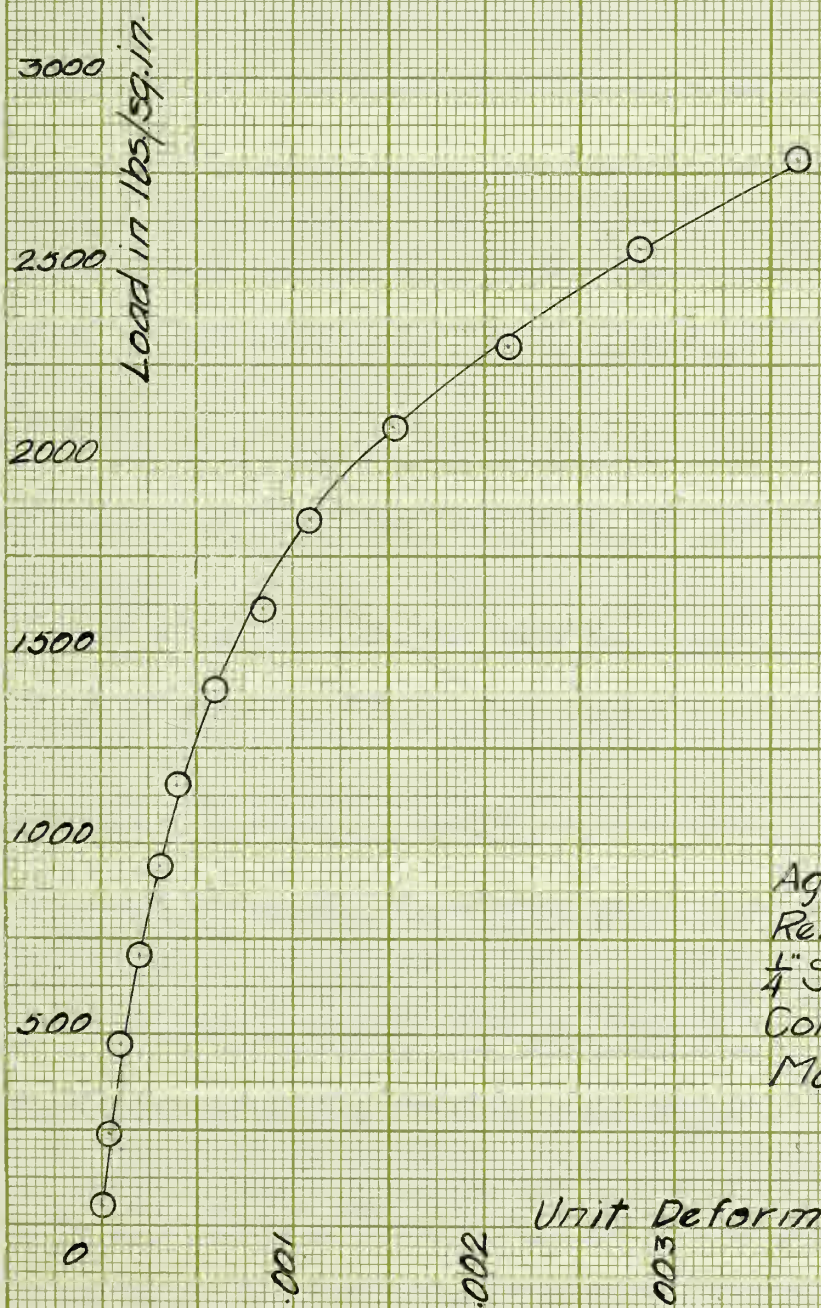
EUGENE DIETZGEN CO., CHICAGO.



Column No.16.
Age 77 days - Length - 5'-2"
Reinforcement:-
$\frac{1}{4}$" Spiral, 1" Pitch, 1.65 %
Concrete - 1-2-4
Max. Load = 4830 lbs/sq.in.

Shaw
James

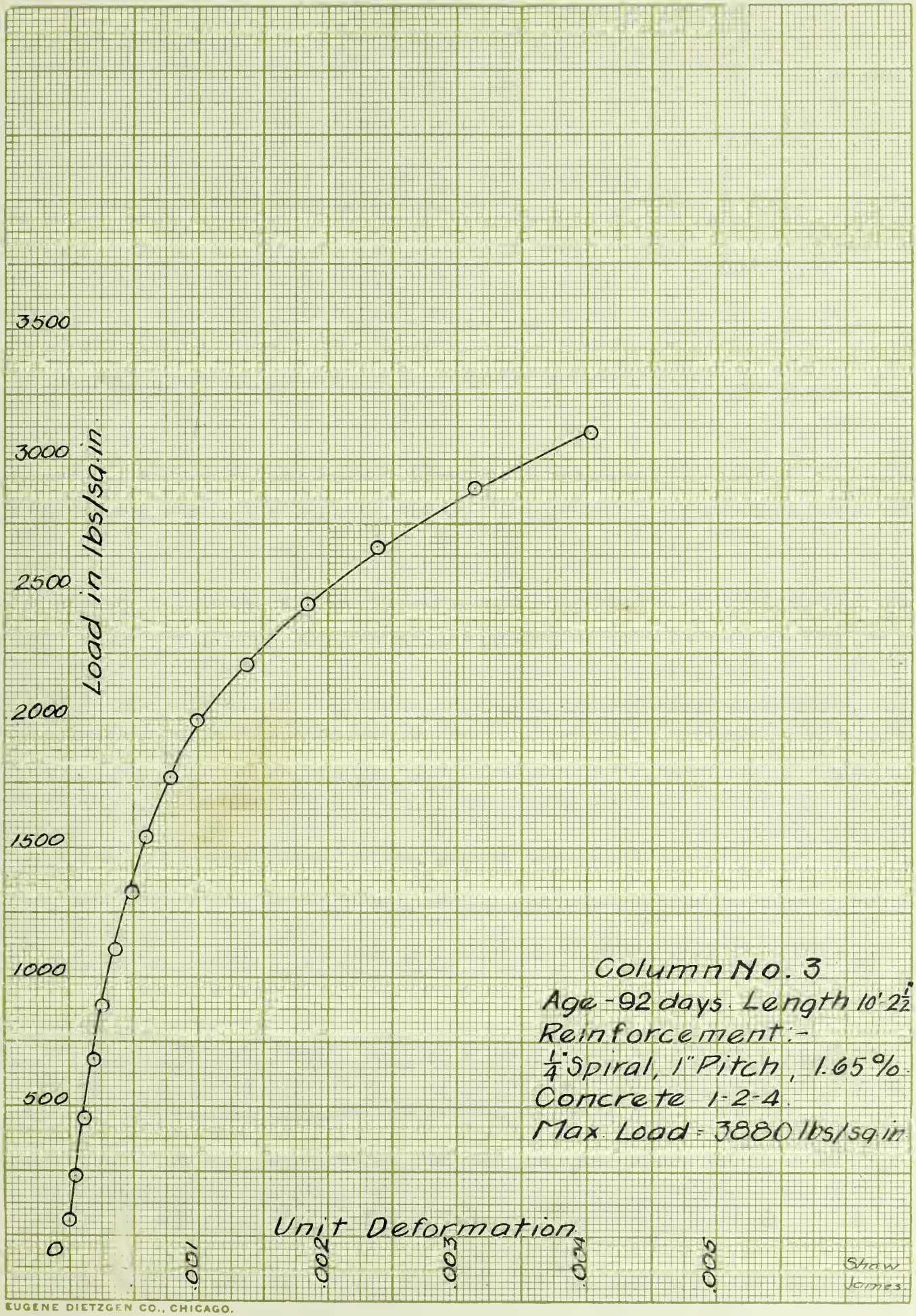
EUGENE DIETZGEN CO., CHICAGO.



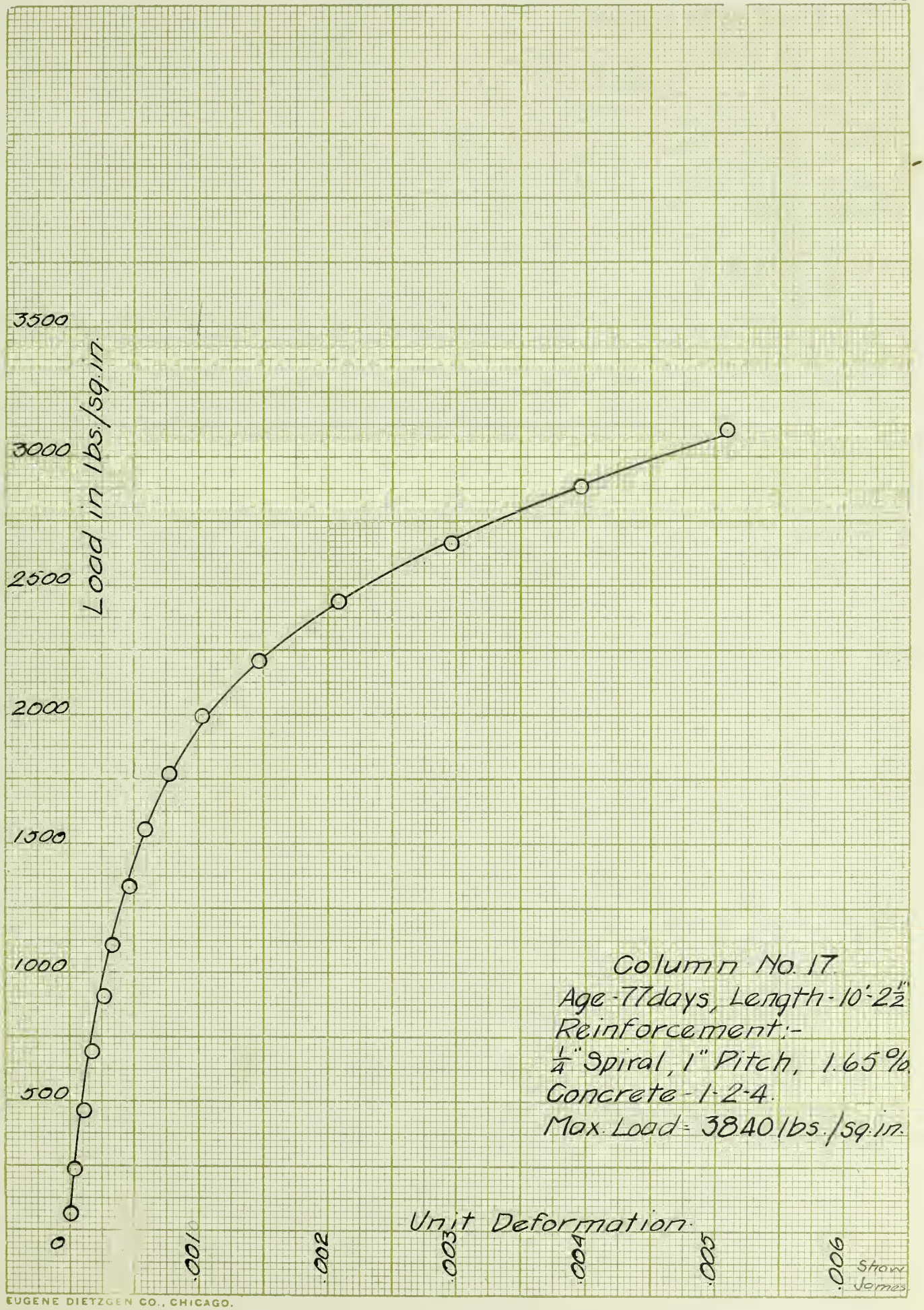
Column No 24.
Age - 62da. Length - 5'-1½"
Reinforcement:-
¼" Spiral, 1" Pitch, 1.65 %
Concrete - 1-2-4.
Max. Load. = 4790 lbs/sq.in.

Shaw
James

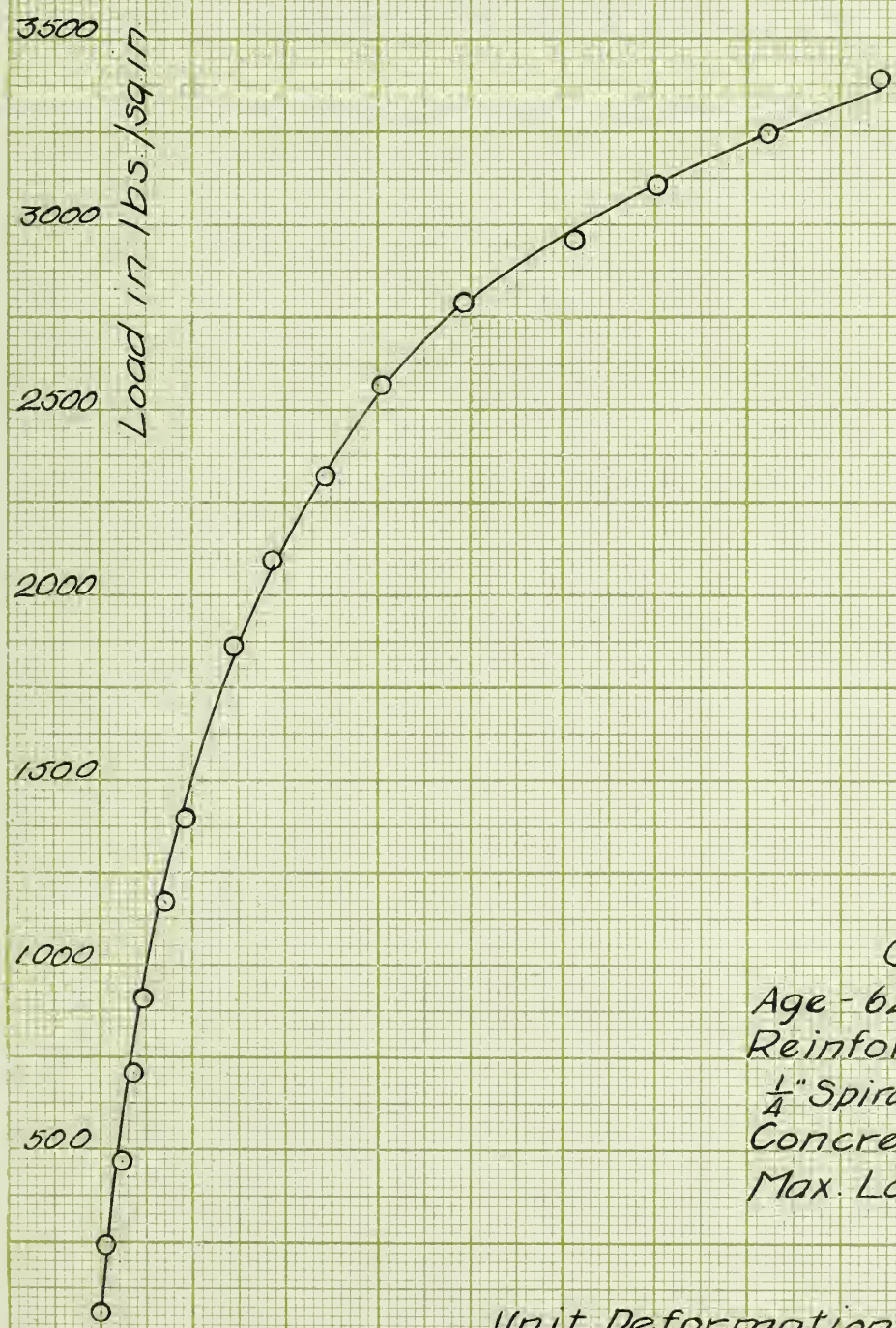
EUGENE DIETZGEN CO., CHICAGO.



EUGENE DIETZGEN CO., CHICAGO.



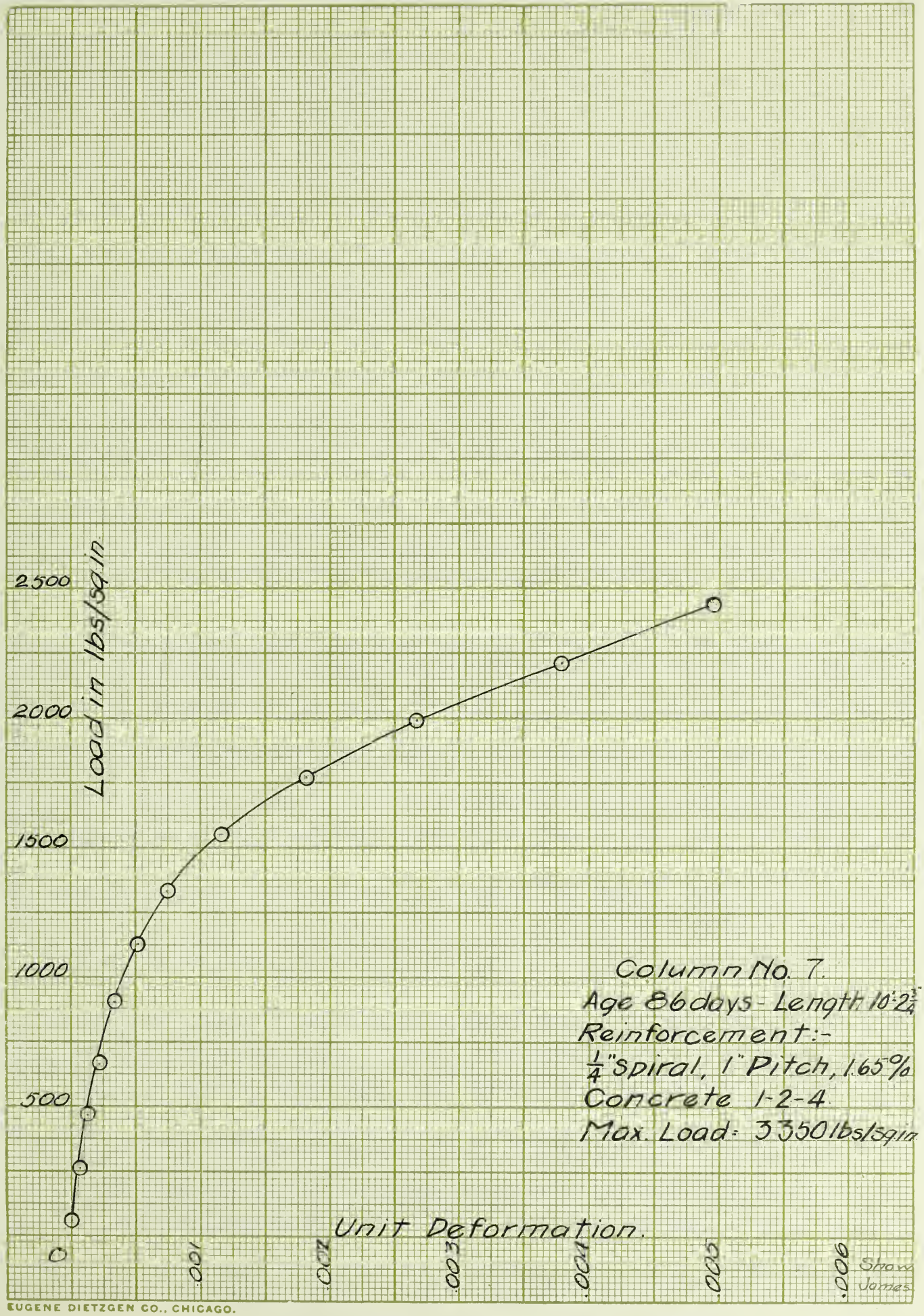
EUGENE DIETZGEN CO., CHICAGO.



Column No 28.
Age - 62 days. Length - 10' - 2 1/4"
Reinforcement:-
1/4" Spiral, 1" Pitch, 1.64 %
Concrete - 1-2-4.
Max. Load = 3850 lbs/sq.in.

Shaw
James

EUGENE DIETZGEN CO., CHICAGO.



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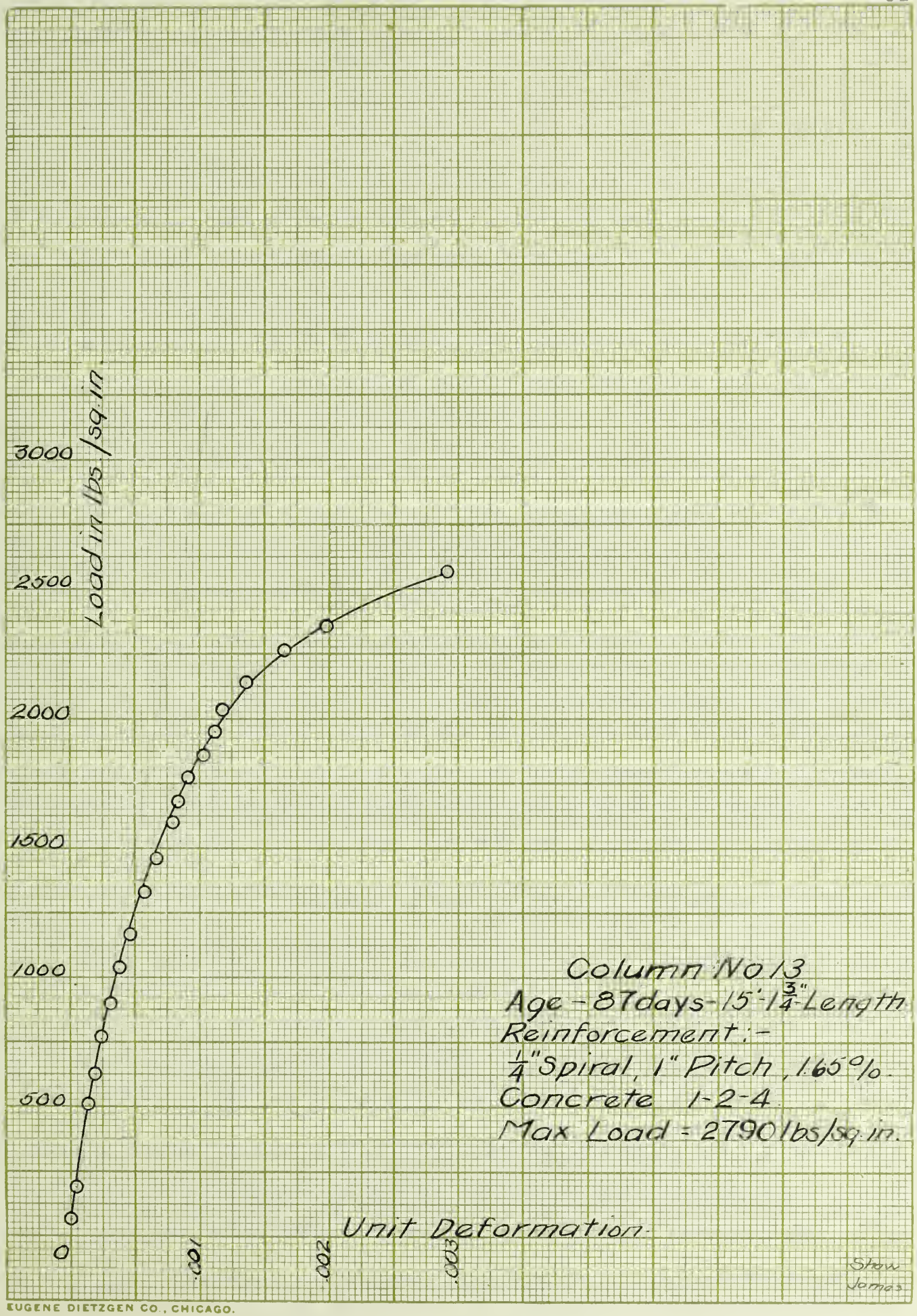

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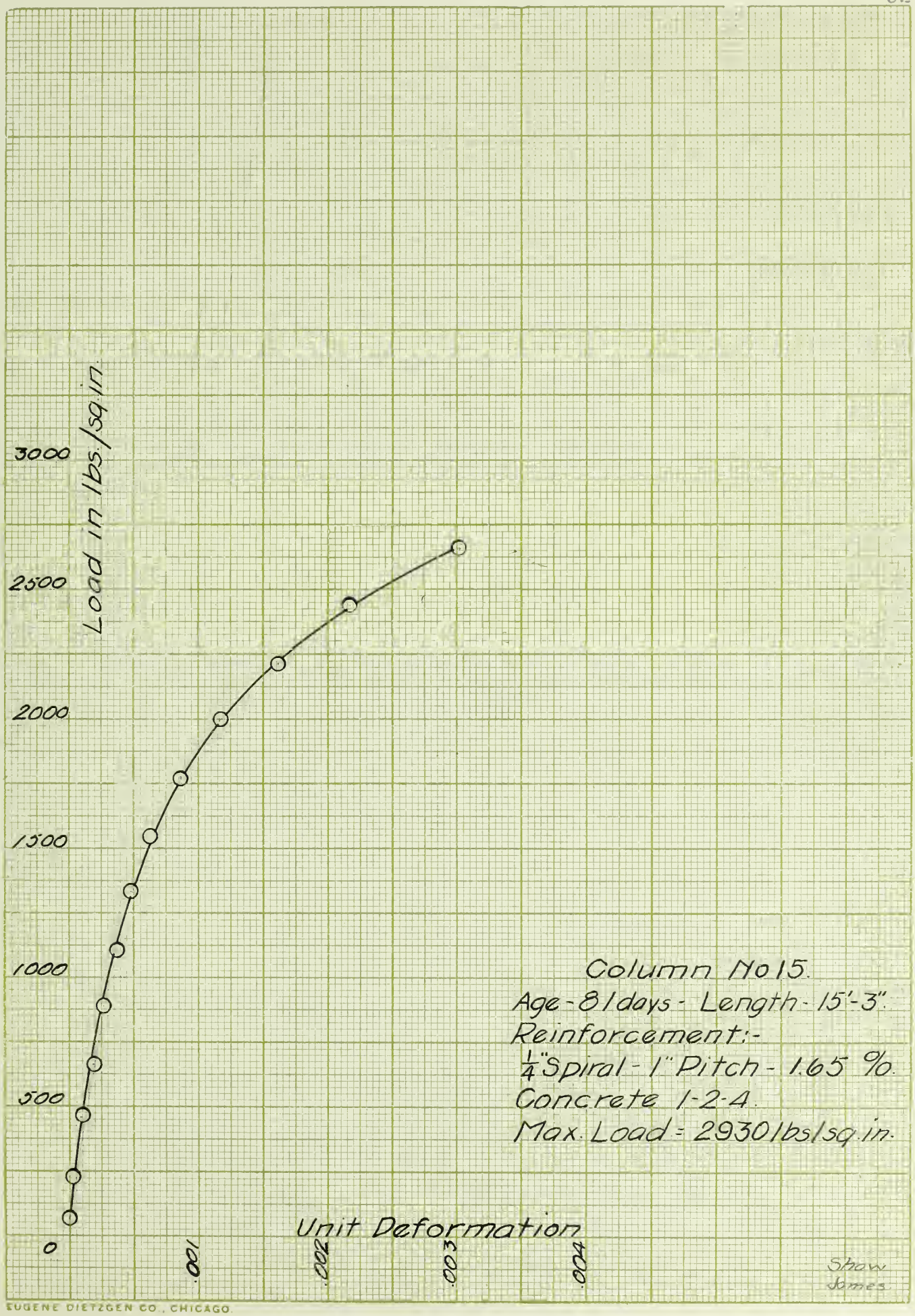
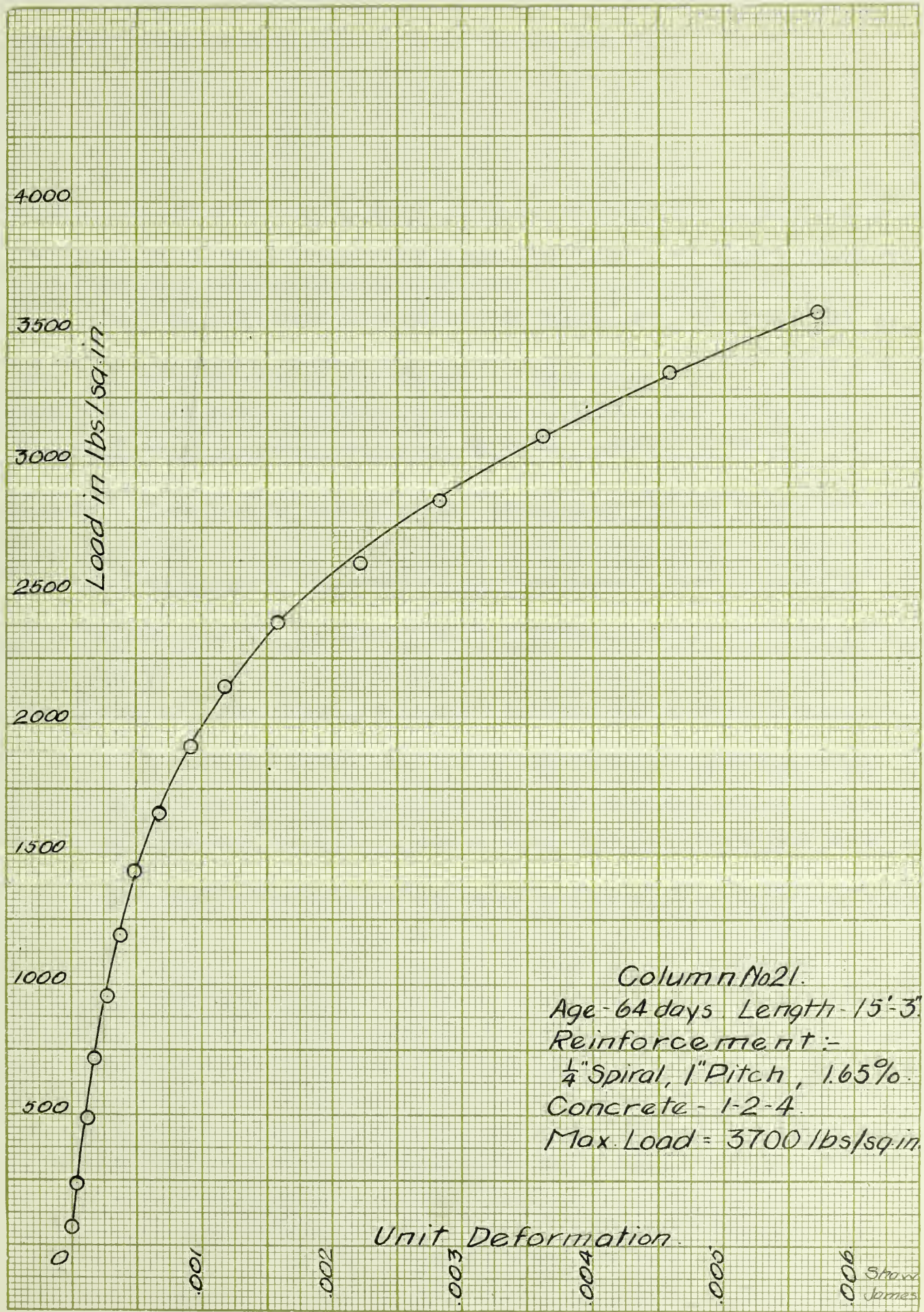


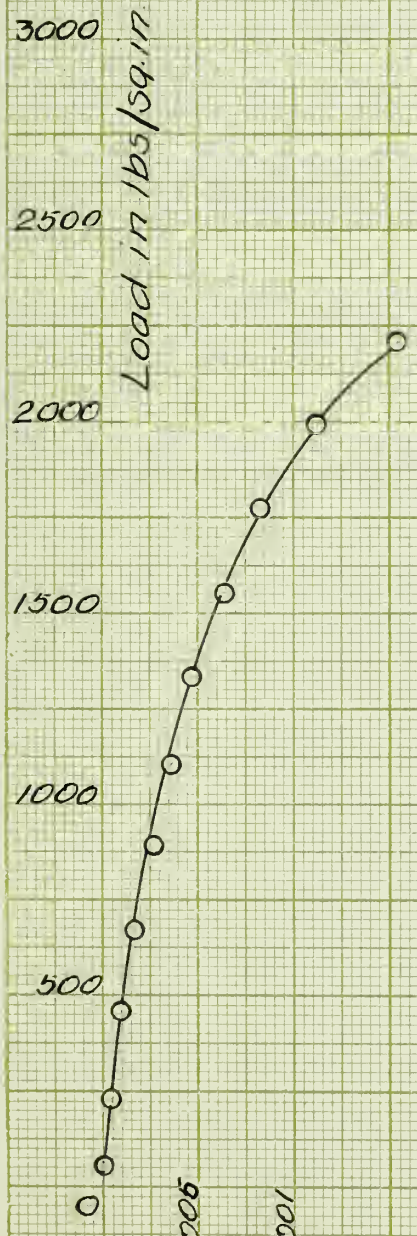
Column No 15.
Age - 81 days - Length - 15'-3".
Reinforcement:-
$\frac{1}{4}$" Spiral - 1" Pitch - 1.65 %.
Concrete 1-2-4.
Max. Load = 2930 lbs/sq. in.

Shaw
Jones

EUGENE DIETZGEN CO., CHICAGO.



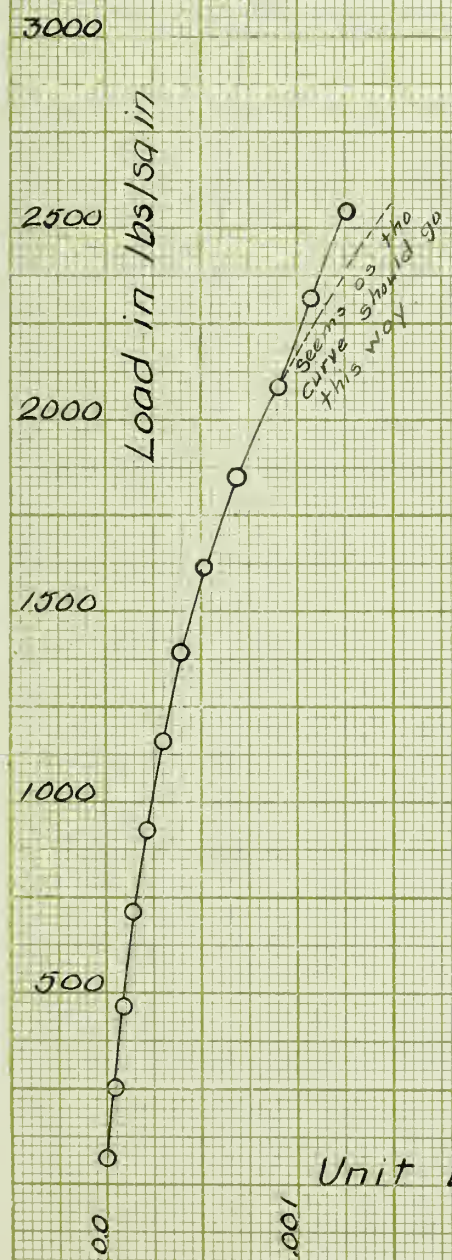
EUGENE DIETZGEN CO., CHICAGO.



Column No. 14.
Age 88 days - Length - 19'-8 3/8"
Reinforcement:-
1/4" Spiral, 1" Pitch, 1.65%
Concrete 1-2-4
Max. Load - 2480 lbs./sq.in.

Shaw
James

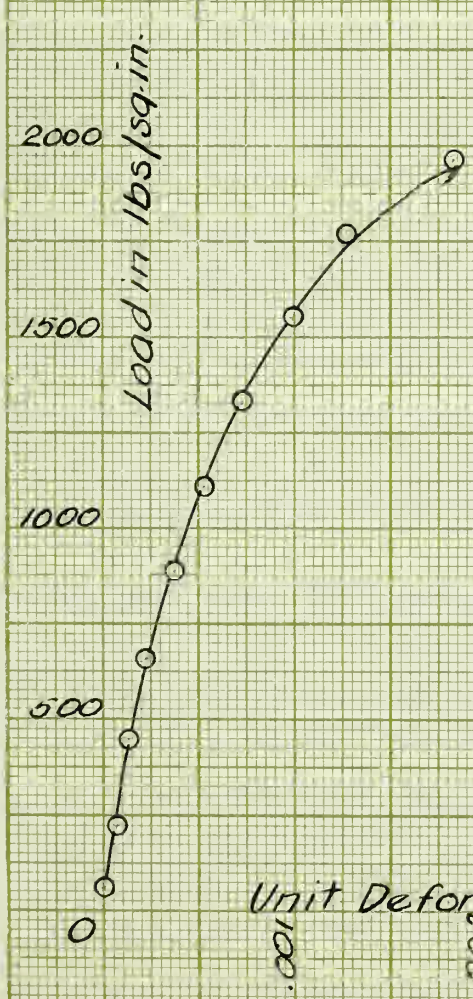
EUGENE DIETZGEN CO., CHICAGO.



Column No 19.
Age – 77 days. Length - 19'-9"
Reinforcement:-
¼" Spiral, 1" Pitch, 1.65%
Concrete 1-2-4.
Max. Load = 2540 lbs/sq in.

Shaw
Jones

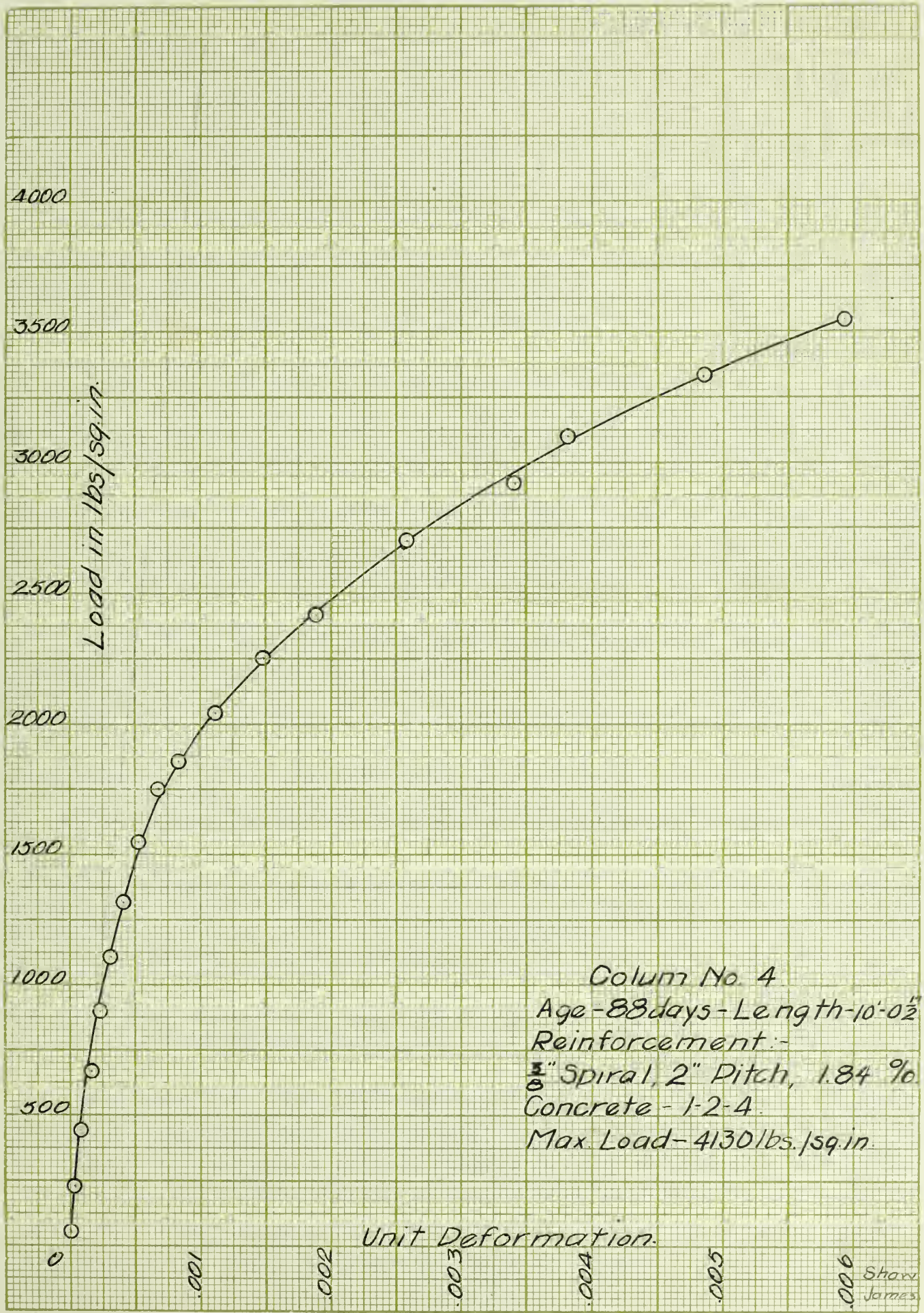
EUGENE DIETZGEN CO., CHICAGO.



Column No 23.
Age 63 days Length 19'-½"
Reinforcement:-
¼" Spiral, 1" Pitch, 1.65%
Concrete 1-2-4
Max Load = 1965 lbs/sq.in.

Shaw
James.

EUGENE DIETZGEN CO., CHICAGO.



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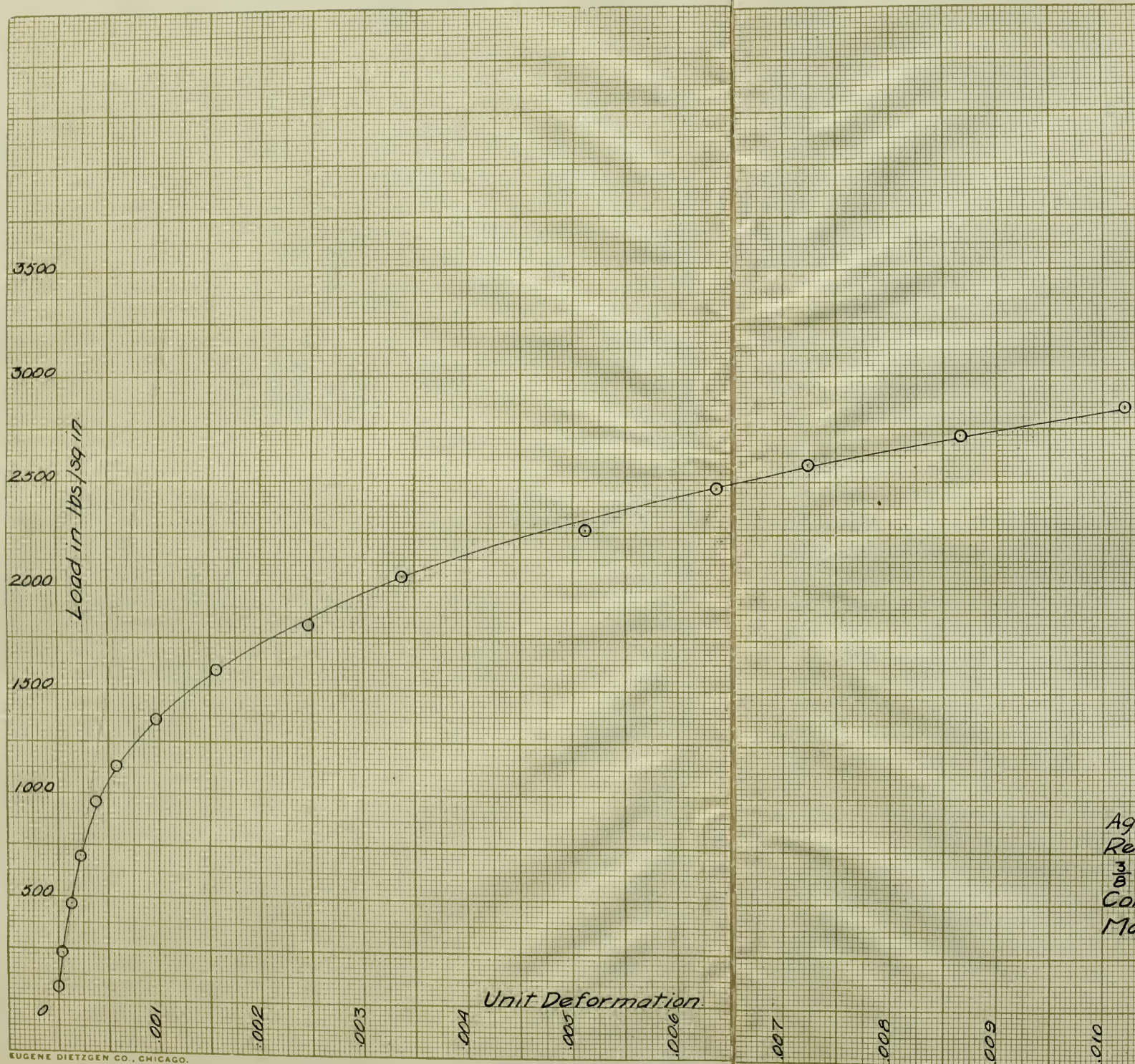

Column No. 41.
Age - 61 days. Length - 10'-3½".
Reinforcement:-
⅜" Spiral, 2" Pitch, 1.84%
Concrete - 1-2-4.
Max. Load = 2930 lbs./sq.in.

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EUGENE DIETZGEN CO., CHICAGO.

Shaw
Jacobs

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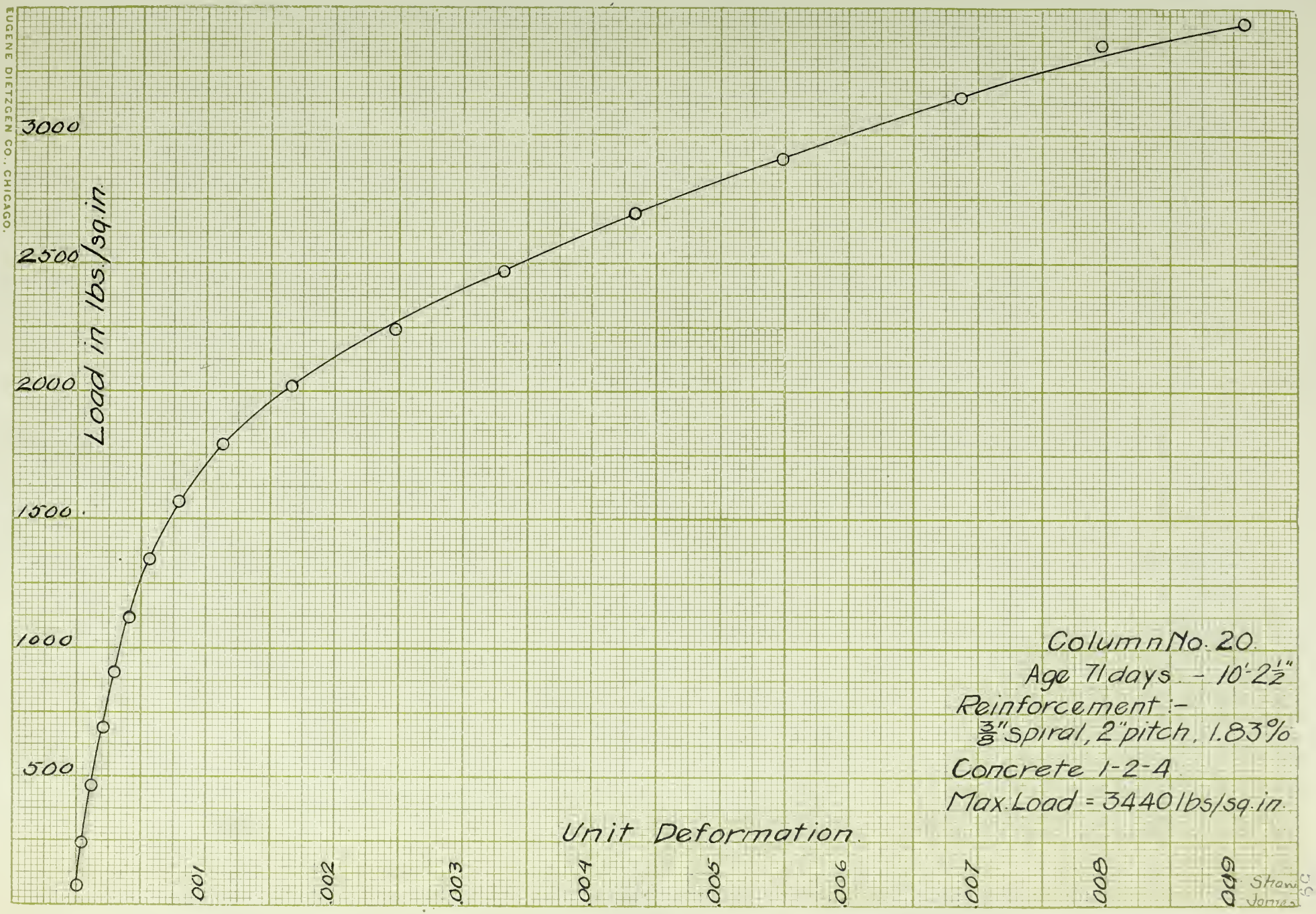
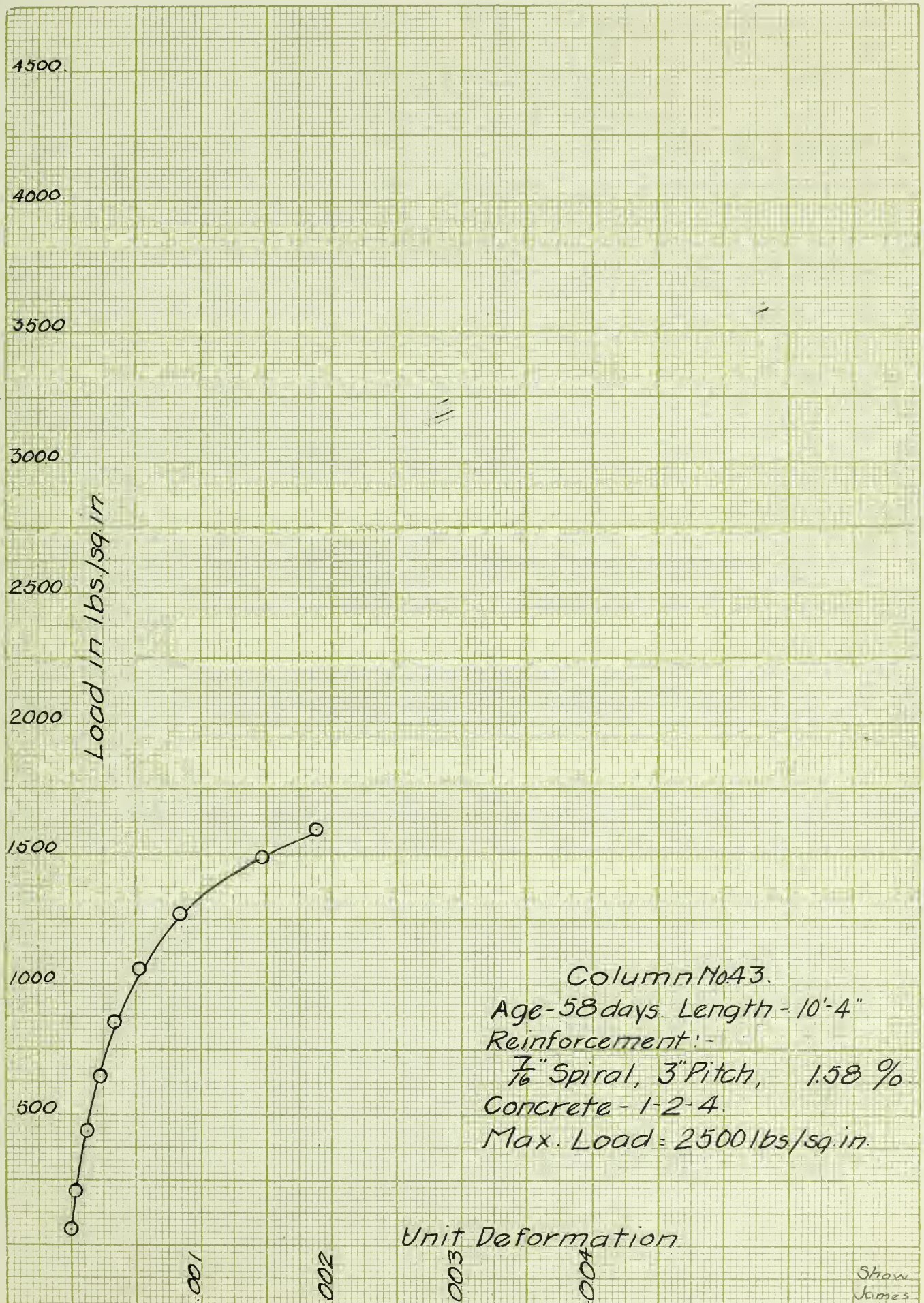


Column No. 20.
Age 71 days - 10'-2½"
Reinforcement :-
⅜" Spiral, 2" pitch, 1.83%
Concrete 1-2-4
Max. Load = 3440 lbs/sq.in.

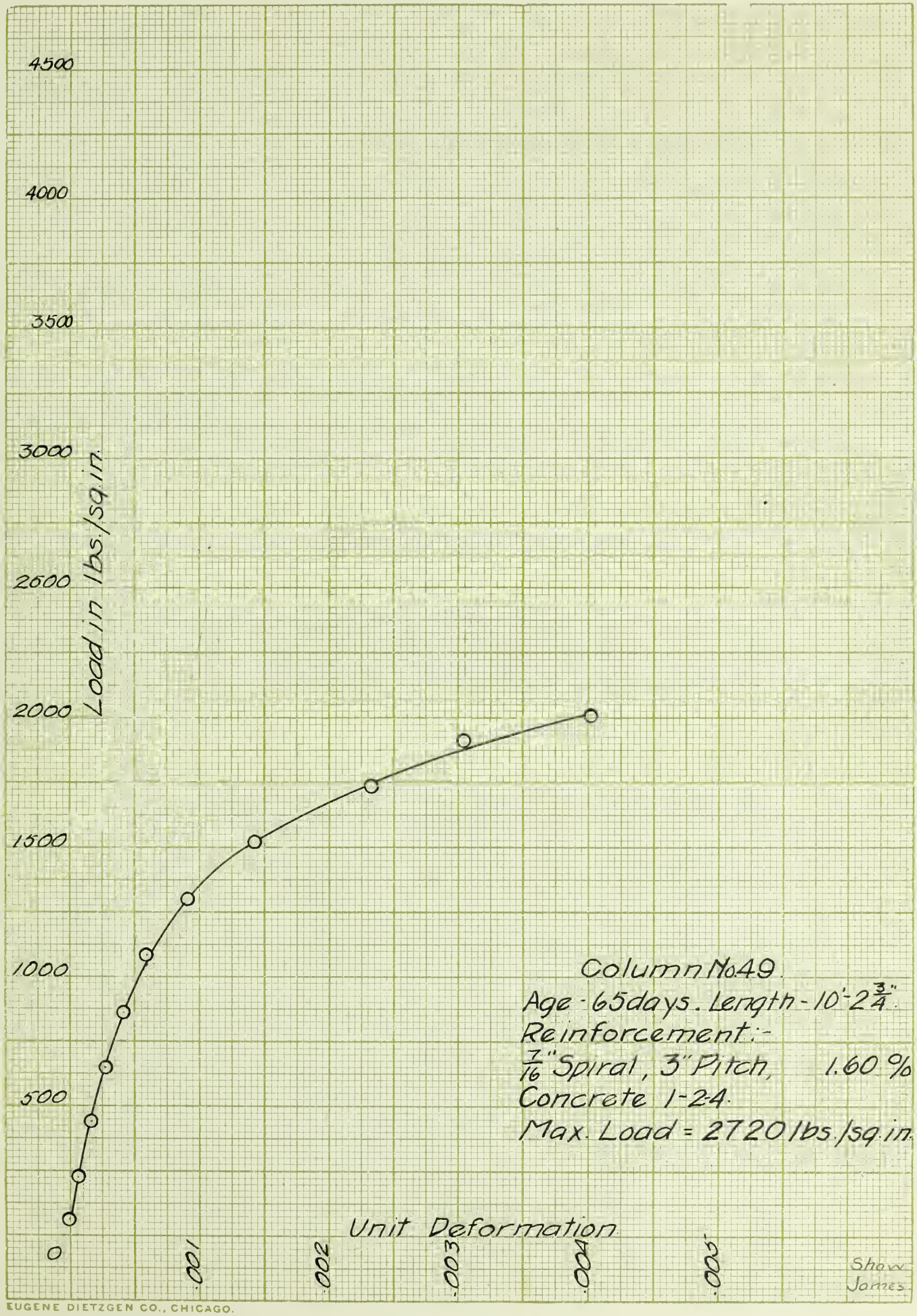
Shown
James



Column No. 43.
Age - 58 days. Length - 10'-4"
Reinforcement:-
7/16" Spiral, 3" Pitch, 1.58 %.
Concrete - 1-2-4.
Max. Load = 2500 lbs/sq.in.

Shaw
James

EUGENE DIETZGEN CO., CHICAGO.



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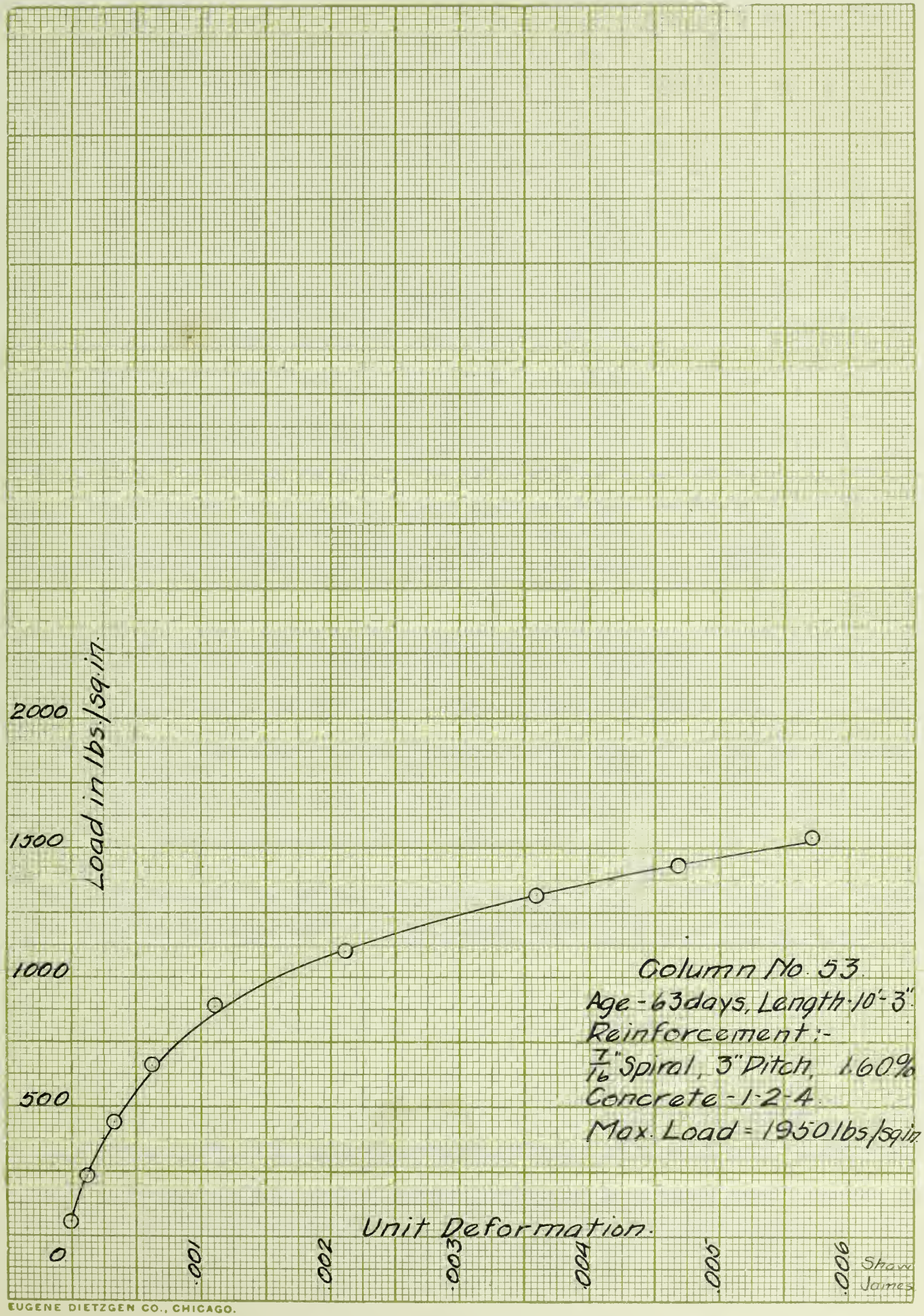

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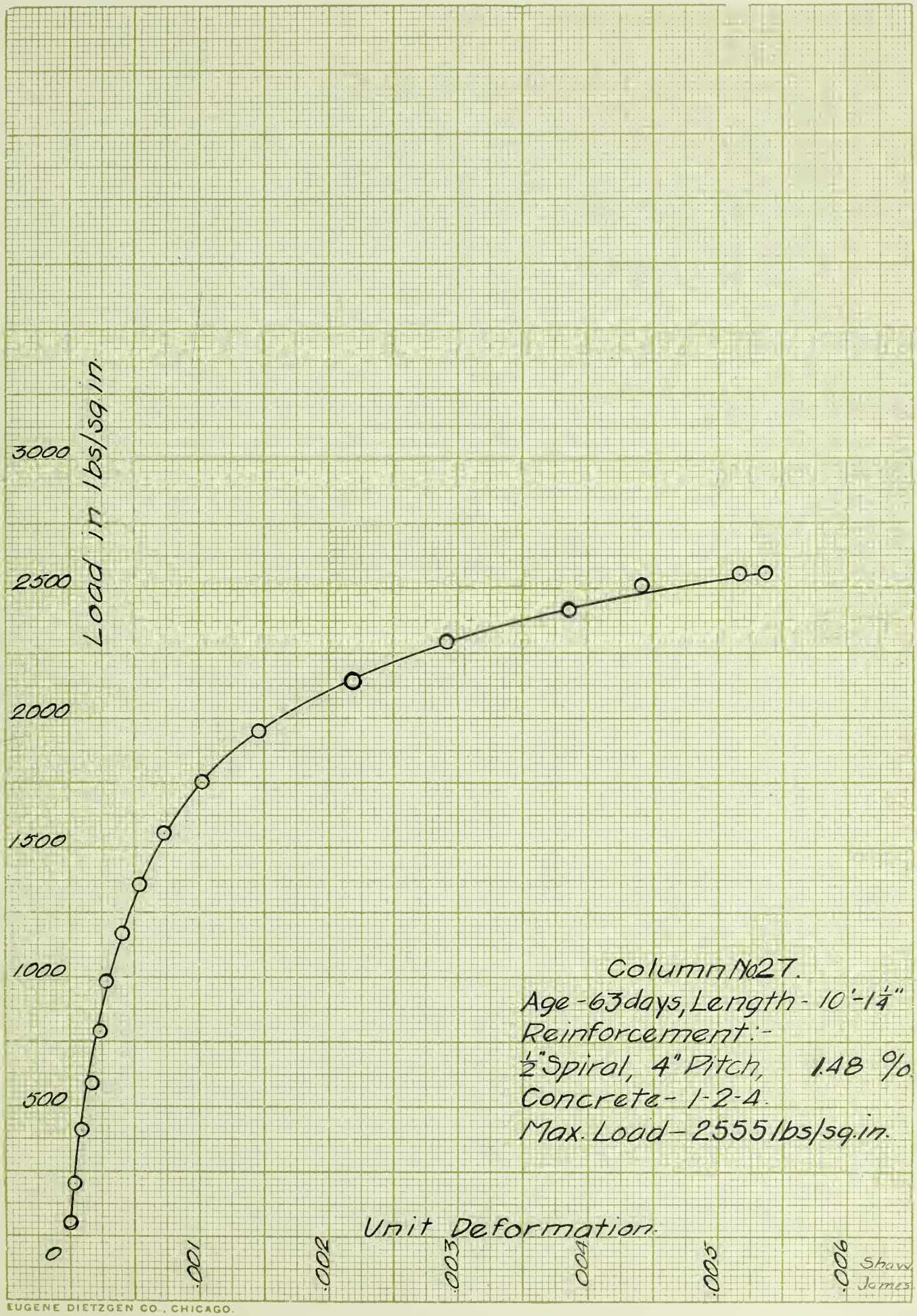

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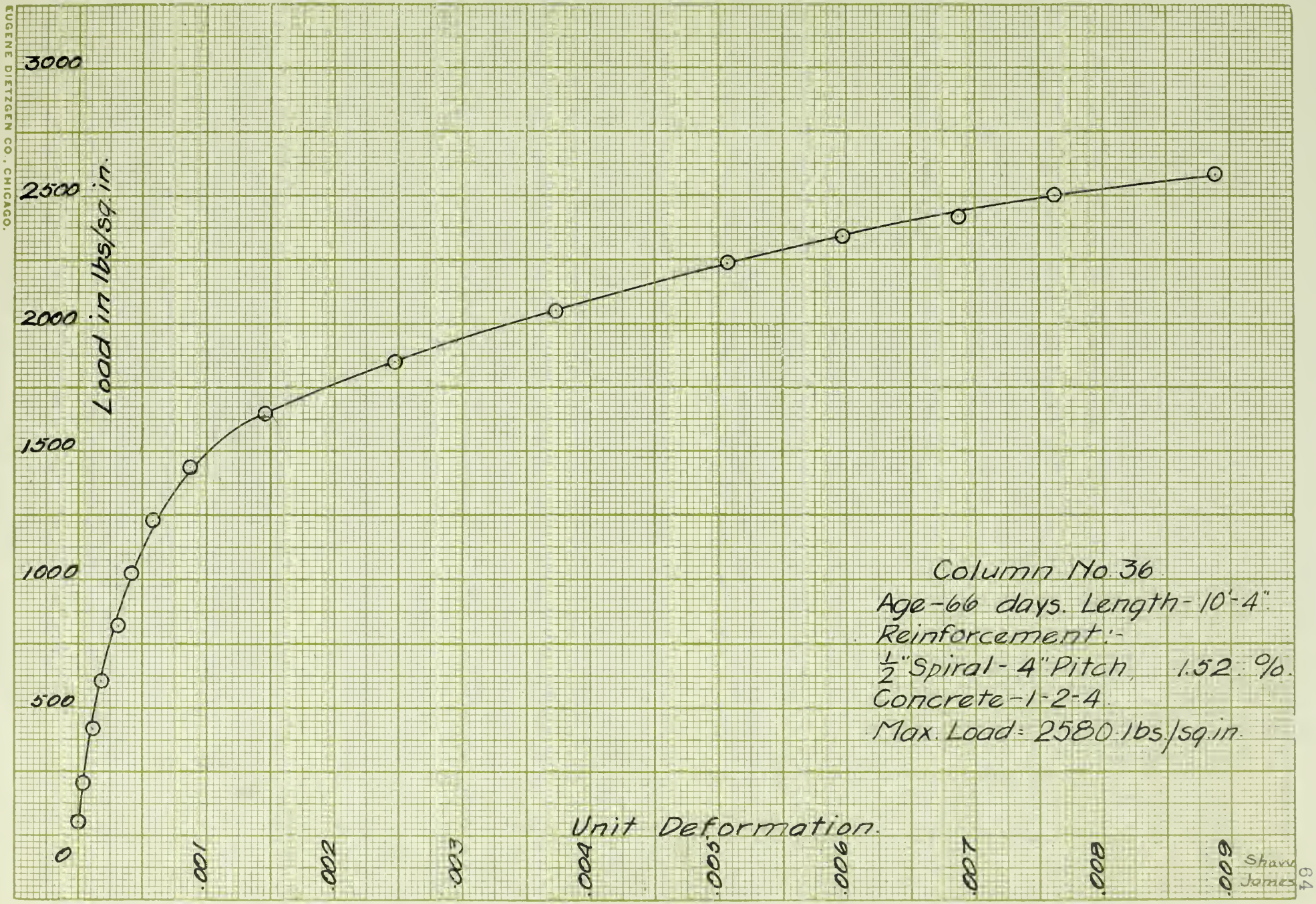

Column No 36
Age-66 days. Length-10'-4"
Reinforcement:-
½" Spiral - 4" Pitch 1.52 %.
Concrete-1-2-4
Max. Load = 2580 lbs./sq.in.

EUGENE DIETZGEN CO., CHICAGO.

Shaw
James

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